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Phase VII
Progress Report

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The authors also wish to thank the many government and industry personnel who continue to cooperate with the research team. As the work continues, the number of contributors (FAA entities, air carriers, and consortiums of industry groups) has grown beyond a reasonable size to individually list all those who have provided guidance and cooperation.

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LIST OF ABBREVIATIONS

A&P	Airframe and Power Plant
AACSB	American Assembly Of Collegiate Schools Of Business
AMAs	Aircraft Maintenance Alerts
AMMS	Aurora Mishap Management System
AMT	Airline Maintenance Technicians
AMTS	Aircraft Maintenance Technology Schools
AMTT	Aircraft Maintenance Team Training
ANOVA	Analysis Of Variance
ASI	Aviation Safety Inspectors
CBT	Computer Based Training
CDs	Campaign Directions
CRM	Crew Resource Management
CTBF	Critical Team Behavior Form
DDA	Documentation Design Aid
ECS	Environmental Control System
EO	Engineering Order
ERA	Engineering Repair Authorization
ERNAP	Ergonomics Audit Program
FAA/AAM	Federal Aviation Administration/ Office Of Aviation Medicine
FAR	Federal Aviation Regulations
FOD	Foreign Object Damage
GDI	Ground Damage Incidents
GTC	Greenville Technical College
HMAs	Hangar Maintenance Alerts
HMV	Heavy Maintenance Visit

HPT	High Pressure Turbine
IBT	Instructor-Based Training
ITS	Intelligent Tutoring Systems
JIC	Job Instruction Card
LMs	Lead Mechanics
MEDA	Maintenance Error Decision Aid
MESH	Managing Engineering Safety Health
MRM	Maintenance Resource Management
N/A	Not Applicable
NM	Non-routine Maintenance
OJIs	On-The-Job Injuries
OJT	On-The-Job Training
PCW	Previously Complied With
PERS	Proactive Error Reduction System
RM	Routine Maintenance
SA	Situation Awareness
SAPC	Skills And Personal Characteristics
SAS	Statistical Analysis Software
SATO	Speed Accuracy Tradeoff
SHEL	Software/ Hardware/ Environment/Liveware
STAR	System For Training Aviation Regulations
SUNY	State University Of New York (At Buffalo)
TAT	Task Analytic Training
TEAM	Tools For Error Analysis In Maintenance
TOME	Tools/Operators/Machines/ Environment
TOQ	Technical Operations Questionnaire

TQM	Total Quality Management
TRACS	Turbine Repair Automated Control System

Chapter 0
PHASE VII OVERVIEW

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0.1 INTRODUCTION

Secretary Peña's Safety Summit held in 1995 has resulted in the Department of Transportation's Aviation Safety Action Plan - "Zero Accidents." Vice president Gore's Commission also identified numerous opportunities to improve airline safety; their Final Report, submitted February 12, 1997 to President Clinton, can be found on the World Wide Web at: http://www.aviationcommission.dot.gov. Such commissions have brought a new level of awareness and focus to applying Human Factors approaches to reducing human errors and developing methods and tools that allow cost savings without compromising safety. The airline industry is showing a great responsiveness in applying human factors methodologies to the maintenance environment. Maintenance Resource Management (MRM) or Technician Resource Management (TRM) using Crew Resource Management (CRM-Human Factors concepts is being viewed favorably by many airlines. Continental Airline's Crew Coordination Concepts (CCC) program for its maintenance personnel is an example of this effort. Airlines are trying to control and reduce "Human Error" and are moving away from "blame the technician" approach to using structured methods to identify the root cause of the errors. The Maintenance Error Decision Aid (MEDA), developed by Boeing in cooperation with the Federal Aviation Administration (FAA) and various airlines, is an example of this approach. With human error being the # 1 cause of aviation incidents, it is evident that applying human factors principles to aviation is the best optionfor the worldwide air transport system to continue to maintain and improve air safety.

The Office of Aviation Medicine (AAM) has conducted human factors-related research in aviation maintenance since 1989. The research ranges from basic scientific experimentation in laboratories to applied studies in airline working environments. The philosophy of this research program has been that "good science" must be the basis for "good practice" and the research conducted must have demonstrable benefits to the Aviation Industry. For this to happen, the end user of the research must be involved in all stages of the research. As such, the researchers in this program have actively sought input from airlines and FAA organizations to define, develop and evaluate the research initiatives.

There has been a strong emphasis on transitioning the research products to the industry. For example one major air carrier is using maintenance workcards that have been redesigned as part of the research. The FAA Flight Standards Service (AFS) is currently deploying the second version of an operational portable computing system called OASIS (On-line Aviation Safety Inspection System). Five hundred AFS Inspectors will be equipped with this new system by the summer of 1997, with a plan of all Inspectors receiving the system by 1999. OASIS was an offshoot of thepen-computing job aid developed as part of this research program. These and other research products and procedures generated by the research program have continued to demonstrate the effectiveness of using human factors principles in the aviation maintenance.

The research program has conducted 11 workshops on Human Factors in Maintenance and Inspection attended by over 1400 industry participants. In eight years, the research program has generated over 200 technical reports, journal articles, and presentations at industry meetings. Five CD-ROMs have been published so far and distributed to over 4000 recipients. A homepage has also been established on the world wide web of the Internet to disseminate Human Factors Information to the aviation community (http://www.hfskyway.com).

0.2 CHAPTER ABSTRACTS

This report describes the research activities performed during Phase VII of the research program. Each of the research activities is summarized below.

0.2.1 Advanced Technology in Aircraft Maintenance: The Turbine Repair Automated Control System (TRACS) (Chapter 1)

Each year, the research program investigates how advanced technology can be used to improve the safety and efficiency of aircraft maintenance operations. This year's project focused on automation of information flow in repair shops. A prototype system was developed to aid airline technicians in tracking, repairing and returning jet engine parts back to serviceability. This project demonstrates that task-centered information systems are feasible for supporting information flow in repair shops.

0.2.2 Re-purposing the System for Training of Aviation Regulations (STAR) to Aid On-the-Job Training for Aviation Safety Inspectors (Chapter 2)

This project is the third and final research phase for the System for Training of Aviation Regulations (STAR). The first two phases developed and evaluated an advanced computer-based training approach to teaching the Federal Aviation Regulations (FARs) to students in Part 147 schools. The approach incorporates multimedia presentations and storytelling techniques within several different computer-based learning environments. This year's effort involved re-purposing this information and structure to provide On-the-Job Training (OJT) to FAA Flight Safety Inspectors.

0.2.3 Supervisory Task Analysis: Aircraft Maintenance Environment (Chapter 3)

Task Analysis is a human factors technique that has been applied previously in the research program to identify training or job aiding needs. This year's project focused on analyzing the tasks of first and second level maintenance supervisors (foremen and lead mechanics). This chapter details the methodology and results of the task analysis which identified the need for improved training for new foremen and lead mechanics. A preliminary curriculum outline for leadership training is provided.

0.2.4 Documentation Design Aid Development (Chapter 4)

The Documentation Design Aid project follows several years of studies related to human factors in aviation maintenance task documentation. Previous projects have shown that it is possible to substantially reduce human errors in reading and interpreting documents, such as workcards, by incorporating human factors guidelines into document design. The current effort identified issues in the existing process for generating, testing and issuing of Engineering Orders (EOs) by leading a focus group at a partner airline. A Documentation Design Aid (DDA) was then developed using the technical literature on human performance in information transfer tasks. The project concluded with a field evaluation of both paper and software versions of the DDA. The evaluation showed that first-time technical users of the Document Design Aid (with less than 20 minutes of training-plus-quiz) were able to find about a third of all the expert-recommended human factors improvements in a typical Engineering Order within an hour.

0.2.5 A Proactive Error Reporting System (Chapter 5)

One approach to controlling maintenance errors is to develop error reporting systems which allow errors to be tracked, investigated, and analyzed. In the first phase of this project, a unified error reporting format was developed in response to the realization that current information about errors is dispersed in various systems and formats. This year's effort expanded on the concept of reactive error reporting and post incident analysis to develop a more proactive approach to preventing errors. The approach identified root causes for Ground Damage Incidents and linked these errors to known solutions. The researchers found that substantial error data, now being captured by error reporting systems, can be used to develop more proactive systems. Since the data on errors and solutions is not currently available, further development of the Proactive Error Report System is not planned.

0.2.6 Role Of Computers In Team Training: The Aircraft Maintenance Environment Example (Chapter 6)

Last year the research program identified the need for training aviation maintenance technicians to work as teams. A multimedia program called Aircraft Maintenance Team Trainer (AMTT) was developed to provide team training to aviation maintenance technicians. In this year's effort, the prototype AMTT computer-based training program was evaluated. The study showed that computer-based training is just as effective as instructor-led training in teaching "soft" skills (i.e., communication skills, interpersonal relationship skills, leadership skills, and decision making). As a result, the training program was modified for general distribution to the aviation maintenance industry on a standalone CD-ROM.

0.2.7 Creation Of Team Situation Awareness Training For Maintenance Technicians (Chapter 7)

The task represents the second phase of a three-phase effort. Phase I, completed last year, studied how the situation awareness concepts, developed for pilots and air traffic controllers, could be applied to aviation maintenance teams. This chapter documents the Phase II development effort. An 8-hour instructor-led course on Team Situation Awareness for maintenance technicians was developed in conjunction with aviation maintenance technicians at a partner airline. The objective of this curiculum is to equip Technical Operations personnel with the skills and abilities to develop an awareness and understanding of factors that affect SA in the maintenance domain and team processes. Five SA concepts are taught: 1) Shared Mental Model, 2) Verbalization of Decision, 3) Better Shift Meetings and Teamwork, 4) Feedback, 5) SA Errors. Materials include MS Office PowerPoint slides, group activities, and a Facilitator's Handbook. The PowerPoint slides are provided as a chapter appendix.

Chapter 1
ADVANCED TECHNOLOGY IN AIRCRAFT MAINTENANCE: THE TURBINE REPAIR AUTOMATED CONTROL SYSTEM (TRACS)

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1.1 INTRODUCTION

Repair shops form a critical component of the maintenance and inspection environment. The increasing complexity of information demanded by mechanics as well as the accuracy required for accountability necessitates the use of computerized job aids. Such a system has a potential to reduce error, mitigate such error if it occurs, and generally promote safety and efficiency in repair shop environments.

Under grant from the FAA Office of Aviation Medicine, Galaxy Scientific Corporation conducted task analysis and job aiding research to identify the human factors issues related to communication and information flow in the turbine repair shop at Delta Airlines. Implementing advanced technologies used and proven in earlier FAA projects, we have created prototype software running on a pen-based computer designed to support maintenance technicians working in the repair shop environment. The Turbine Repair Automated Control System (TRACS) was designed to assist the mechanics and technicians with a number of traditionally separate tasks. The features include:

- Automation of the current paper-based system of sequencing repair steps.
- Aiding in the decision-making process during sequencing of steps.
- Full hypertext manual documentation with links directly within the repair sign-off process.
- Graphical methods of selecting parts on a turbine module for repair and rebuild.
- Ability to carry the pen computer easily to the point of repair for direct entry of critical. measurements and other data, reducing the possibility of error.
- Friendly, easy to use interface in a point and click window environment.
- Full tracking of parts through the entire repair process, with access to all time and cycle limit information.

1.1.1 Research Goals

The maintenance and repair of aircraft has a direct impact on flight safety. The systems which airlines use to maintain aircraft are frequently inspected by the FAA for obvious reasons. However, recent technological changes have provided a means by which airlines can significantly improve these systems. Many airlines are embarking on implementing new technologies for documentation, process control, compliance, and cost control. ACs which govern these new technologies are slowly being created, but not fast enough to keep up with the pace of change.

The current research attempts to evaluate some of the newer technologies to identify what will and will not be useful to the Airline Maintenance Technicians (AMT) who must use them. The research also addresses the regulatory and safety issues that will be involved during the implementation of new technologies in the maintenance workplace.

To that end, the following research agenda was followed:

- Delineation of the research scope by identification of target shop and parts.
- Task analysis of the AMT job to identify potential redundancies and error-prone situations.
- Information needs analysis so informational requirements of the AMT will be known.
- Collection of all relevant forms and documentation required for maintenance of target parts.
- Three phase, iterative development of a prototype software system to aid AMTs.

- Final evaluation of the prototype system.
- Communication of results to industry and the scientific community.

1.2 METHODOLOGY

The methods used for the present study involved three steps. The first step was a fairly high-level task analysis which helped us to identify the major divisions of labor within the rotor shop. The task analysis gave us a good idea of the general tasks which each category of worker was responsible for completing.[1]

The next step was a detailed information flow analysis, which involved the collection of all of the types of documents used by the workers in the rotor shop and the routes those documents followed. We also analyzed how the documents were appended and updated during the repair process.[2]

The final step in our research was to design a prototype software system using human-centered design principles. We developed the prototype with the continuous feedback from the technicians who would eventually be evaluating the usability and utility of the system.

The following subsections describe the environment in which we conducted our research, the results of the task analysis and information flow analysis, issues raised during these analyses, and a diagram of the repair process. The final subsections describe the consequent user requirements and scope of the prototype design.

1.2.1 Description of the Maintenance Environment

After presentation of the research objectives to Delta Air Lines, members of the engine planning group agreed to allow researchers to use the Rotor Repair Shop as a test bed for the prototype technology. The rotor shop services turbine and compressor modules of jet engines manufactured by General Electric. The rotor shop is housed in the Technical Operations Center, Atlanta, GA. This is Delta's primary maintenance and repair facility. The rotor shop occupies about the space of a football field, including areas for administrative paperwork, mechanical repair, inspection, and storage of parts. The shop is surrounded by many support shops responsible for cleaning, machining, plating, heat-treating, and other jobs related to the repair of jet engines.

One of the reasons for the choice of the rotor shop was because of the historically difficult methods of routing parts for repair, sometimes resulting in rejected parts. The difficulty in routing parts stems from a complex method of repair which must be configured separately for each part. Any system which could simplify or make easier the routing process would potentially decrease human errors as well as improve overall flight safety.

1.2.2 Task Analysis

Because the final objective of the project was to build a prototype system to aid mechanics in repairing parts, we first needed to understand the job as thoroughly as possible. During May and June 1996, we traveled multiple times to the work area and interviewed the AMTs as they were completing tasks. We identified five job classes in the rotor shop. Following is a task description of those jobs.

Work Center Personnel

Major duties of the work center person are:

- Locating parts
- Scheduling parts
- Assembling paperwork needed to repair parts
- Ensuring compliance with regulations by checking for necessary sign-offs
- Controlling part inventory

Inspector

Major duties of the inspector are:

- Visually inspecting parts for flaws and service needs
- Taking and recording measurements to determine whether a part is within limits
- Final inspecting of all parts returning from repair and rework
- Routing parts that require additional rework

Lead Mechanic

Major duties of the lead mechanic are:

- Keeping time and attendance for team members
- Assigning mechanics to jobs
- Checking in all rotors
- Checking compatibility of parts
- Completing daily scheduling for rotors
- Attending rotor repair workscope meeting
- Monitoring manuals
- Originating non-routine repair paperwork
- Inspecting and ordering parts for rebuild of modules
- Final checking and assignment of parts for assembly

Mechanic

Major duties of the mechanic are:

- Following current methods of repairing parts
- Maintaining knowledge about parts
- Routine cleaning of parts
- Servicing parts
- Signing off when steps are completed
- Logging time for repairs

Mechanic Assistant

Major duties of the mechanic assistant are:

- Cleaning parts as required
- Checking and sorting hardware
- Assisting with job duties of the inspector, lead, mechanic, and work center

1.2.3 Repair Process Diagram

Following is an illustration of the process by which modules and parts enter the rotor shop, are disassembled, inspected, routed for repair, and reassembled. It represents the process by which a module is serviced, and the moments at which information is accessed for decision-making. Included in the illustration is the information used during particular steps. These sources of information are contained in boxes resembling gray slips of paper.

The modules are broken out of the engine in the engine shop. A meeting is held to determine the level of repair or maintenance needed for the module. The module is sent to the rotor shop, where it is checked in by the work center, inspected, cleaned, and broken down to component parts. The parts are inspected again and routed for repair. An intermediate inspection takes place to determine whether all repairs have been effectively implemented. The parts are put back together to form the module, and final inspection occurs which allows a module to return to service.

In the diagram, double dotted lines represent the imaginary fence we placed around the rotor shop. Inputs from the cleaning and testing of the part are included in the repair process, but these shops were not involved in the development of the prototype.

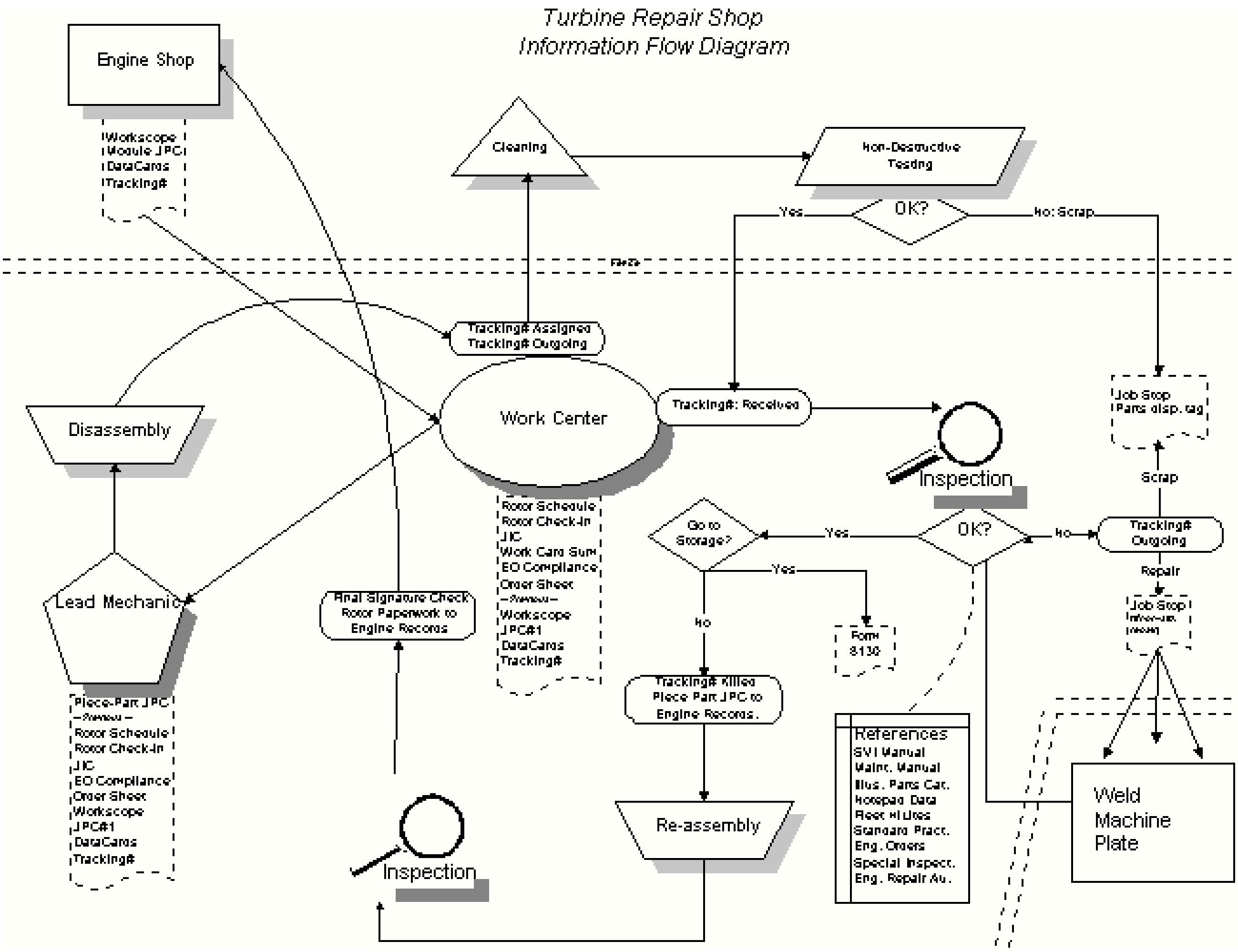


Figure 1.1 Process and Information Flow in the Rotor Shop

1.2.4 Information Analysis

The next item on our research agenda involved an information analysis. This process goes beyond observing what the AMT does during normal work time, but finding out what information is needed to get the job done, and how information flows within the repair system. This was a critical analysis, since the technology we chose to implement would depend on the type of information used in the job. We first identified all of the documents used in the repair shop (such as manuals, orders, repair routing sheets, etc.) and then closely monitored the way the documents were used, processed, and updated.

Table 1.1 describes most of the documents required for the repair of parts and modules in the rotor shop. The interested reader should refer to the help system contained in the prototype for a more thorough treatment of the forms and documents used in the rotor shop.

Table 1.1 Forms and Documents Related to the AMT Rotor Repair Shop

Job Instruction Card	The Job Instruction Card (JIC) controls the assembly and disassembly of the High Pressure Turbine module and its component parts. Mechanics and Lead Mechanics must follow and sign off each step.
Order Sheet	When a module enters the repair shop and is visually inspected, the inspector or lead mechanic determines which parts must be taken out of the module to be serviced. The order sheet is the method by which parts are requested to replace the parts that are pulled from the module for repair.
Shop Order	After a part has been ordered on the Order Sheet (indicating the part needs to be serviced), a Shop Order is generated for the repair of that part. The Shop Order controls many aspects of the repair of a part. The Shop Order begins as a template for a standard repair of the part. To customize the shop order for a specific repair, the lead mechanic must configure the template. This process is called Stamp Steps, because on the traditional paper-based Shop Order the mechanics actually used a rubber stamp to indicate which steps were required for repair.
Job Stop Card	Sometimes a part becomes so damaged that it cannot be repaired, or it will be delayed for an extended period of time. When this happens, a Job Stop Card must be completed in order to let people who may be waiting on the part know that the part has been delayed.
Engineering Order	An Engineering Order (EO) is a required repair of a specific part type, usually mandated by the manufacturer or the FAA. This may occur because of some defect or other event related to the performance of the part.
E.O. Compliance	A form requiring a signature which indicates that a regulatory Engineering Order has been complied with correctly.
Engineering Repair Authorization	An Engineering Repair Authorization (ERA) is a specific, one time authorization of a repair.
Engine Manual	This reference document provides exact instructions for the repair of a particular part or process. It includes tables and technical diagrams.
Process Standard	These are FAA approved standard operating procedures which are specific to individual airlines.
Illustrated Parts Catalog	This reference document gives information about the configuration of various engine parts, allowing mechanics and inspectors to determine the proper compatibility of components.
Form 8130	An internationally recognized standard form for the documentation that a part has been serviced by an authorized repair station. Parts can be resold to other airlines by using this form.

Issues Observed from Information Flow Analysis

Based upon our analysis of the documents used in the rotor shop and the methods by which they were updated, we observed some potential areas that could be improved with the use of a job aid system. The following paragraphs describe those broad areas that were identified.

Gathering Information

Because of the many sources of reference information that AMTs require to complete their work, a great deal of time is lost gathering that information. In the repair shops, time is a critical factor in maintaining commercial viability while at the same time maintaining a proper level of safety. These two forces are opposed to one another. Providing the information necessary in a timely fashion would greatly increase the overall safety of the operation. Most repair stations keep their reference manuals on microfiche or paper. Providing the same information at a single location in a digital format would greatly increase the speed of information retrieval.

Recording Information

At the time of the analysis, we noted that all of the recording of data such as part measurements, serial numbers, historical cycle information, etc. was accomplished on paper forms. These forms are eventually stored in the engine records area after a part has been serviced. Therefore, logged data is unavailable during later repairs and previous part servicing histories are not utilized. Accessing the data during FAA inspections is also cumbersome, though within regulation. Providing electronic forms for logging data would eliminate the need for the deep storage of paper records, and would provide the AMT with historical records on demand.

Redundancy

Since most of the repair system is recorded on paper, the process of customizing that system for each part is extremely tedious. Part routing is accomplished by stamping the appropriate steps required for repair if the part requires a standard repair. If the part requires additional rework, the routing process becomes significantly more complex. A large part of the handwritten information is redundant, such as the numerous times a technician must write the same serial number on multiple forms. Time could be saved and errors could be reduced if electronic forms were provided which automatically transferred information across multiple forms. Data sharing would reduce routing errors, allowing AMTs to focus on safe, quality work.

Information Loss

AMTs must handwrite all changes to the standard repair process (this process is called rerouting) and are not allowed to reuse previous routing work from similar repairs by federal regulation. This represents a type of expert information loss. Creating a new routing document is necessary for a paper based process of repair; allowing technicians to use copies of previous reroutes would present a safety risk because copied information could not be altered to fit the current repair. However, if the technicians were allowed to create an electronic "master copy" of reroutes (also known as a template) and had the ability to quickly make changes to this master copy, there would be no reason to create new routing documents whenever there was a deviation from the standard routing. In fact, this would significantly improve safety by allowing the AMT to utilize the latest knowledge in completing the job. This information could also be made available to technical publishers as well as regulators, increasing the likelihood that the information is current.

1.2.5 User Requirements

Based on the observations listed above, we identified a set of challenges for designing the prototype:

- Provide all reference information needed by the AMTs in a digital, searchable format.
- Provide easy links to reference information at the moment it is needed.
- Create an electronic system for part repair which corresponds to the paper-based system.
- Make the electronic system intuitive and easy to use.
- Implement the electronic system on portable computers so that AMTs can record critical data at the point of measurement.
- Eliminate redundant data logging.
- Give the user the ability to track part status and comments from other shops at any time in the repair cycle.
- Provide a method of updating process control information.
- Give experts the ability to save routing knowledge and routing templates for use in future repairs.

1.2.6 Research Scope and Target Parts

Since the research objective was to develop a proof-of-concept prototype, we decided to limit the scope of the prototype to include only two parts that are repaired by the rotor shop. The two parts selected were both from the General Electric CF6-80 jet engine, High Pressure Turbine (HPT) module. We selected the Stage 1 Shaft/Disk and the Thermal Shield because these parts are two of the most expensive and difficult to route parts in the shop. The selection of parts was made primarily by the AMTs who assisted us in our research.

The scope of the project was also limited by the beginning and endpoint of the repair process. Although theoretically we could have followed the parts from the moment they are removed from the aircraft to the time they return, we made the conscious decision to define our research universe more narrowly. This gave us the opportunity to better control the inputs and outputs of the system, as well as maintain a strong focus on the actual repair of the parts. Thus we drew an imaginary fence around the rotor shop and its support shops (Figure 1.1). The prototype software tracks HPT modules from the time they are delivered to the rotor shop, disassembled into components like our target parts, repaired, put back together, and sent out of the shop again.

1.3 PROTOTYPE DESIGN

The design of the prototype occurred in three distinct stages which we called initial test, intermediate test, and final evaluation. The iterative nature of the design allowed us to get continuous feedback from the same group of AMTs who had given us information about their jobs and repair process. By giving the technicians the chance to make suggestions for the software, we had a much better chance of creating software which was properly functional and user friendly. This iterative process of creating software, in which the end user has a great deal of power in determining interface and functionality, is termed user-centered design.[3,4,5]

1.3.1 Initial Designs

The first major function we decided to develop for the prototype was the repair process of the two target parts. This process was primarily controlled by the Shop Order, which is simply a sequence of steps for the repair of the HPT parts. We gathered together the Shop Orders for the Thermal Shield and the Stage 1 Shaft/Disk and created an electronic version of this sequence with the ability to sign off each step.

The Main Menu (Figure 1.3) of the program allowed technicians to move between various functions of the program. The Order Sheet (Figure 1.4) allowed technicians to graphically identify which parts of the module need to be removed for repair. In addition, we created a version of the Data Cards which described time and cycle limits for the parts. These data cards assist the technicians as they are routing the part. Part routing refers to the task of identifying which repair steps are required to make the part serviceable. The method by which a technician routes a part is by "stamping steps" on the shop order with a personalized rubber stamp. These stamps flag the mechanics who will be completing the work.

The Shop Order (Figure 1.5) was significantly improved based on recommendations to include inserting, moving, changing, and deleting steps. The ability to short sign a step was added. Digital reference documentation was included as well for both of the target parts (Figure 1.2). The ability to view the appropriate reference from within the Shop Order form and to click on a button and retrieve the actual document, was seen as a great improvement. With this fairly simple addition to the software, feedback from the AMTs was extremely positive. In fact most of the AMTs asked when the system was to be implemented on the shop floor. We continued to point out that the prototype was designed for proof-of-concept, and that the airline partner would have to be the managers of any change to its current system.

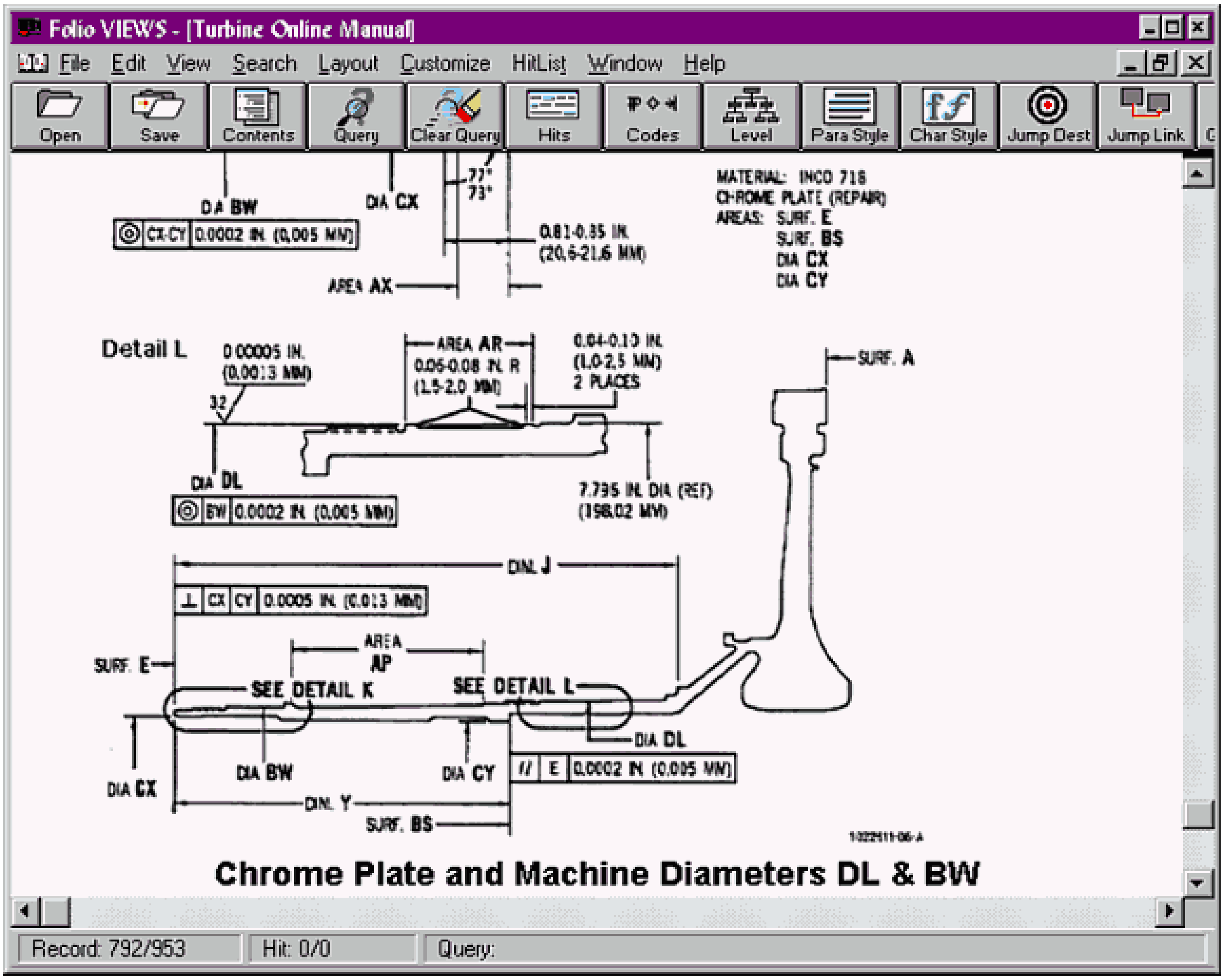
1.3.2 Final Design

At the time of the final evaluation, we had implemented all of the suggestions for improvements given during the initial phases of design. The Repair Code Editor was the most recent change to the software. This feature allowed the AMT to configure templates for the repair of a particular part. There were two components to the editor -- Presets and Repair Codes.

The Presets window (Figure 1.6) allows the AMT to "stamp steps" within the original Shop Order and save that series of activated steps for future use. A menu of saved Presets is available at the time the AMT needs to stamp steps. By choosing one of the Presets, the technician automatically stamps all steps for that configuration rather than having to stamp each step individually.

The Repair Codes window allows the AMT to create a customized sequence of repair steps which could be saved for later reroute work. For example, rather than creating and inserting steps one at a time on a shop order, the AMT can simply choose a previously saved Repair Code, and insert the whole batch of steps at once.

The interface was significantly altered as well to include such features as editable fields for part information on the Header window of the Shop Order. Use of panes within windows was another feature added to the software to increase the legibility and organization of individual screens. Buttons were changed to maintain consistency throughout the program, and a full help system was added. These features improved the overall usability of the software. Following are some sample screens from the TRACS software.



Chrome Plate and Machine Diameters DL & BW

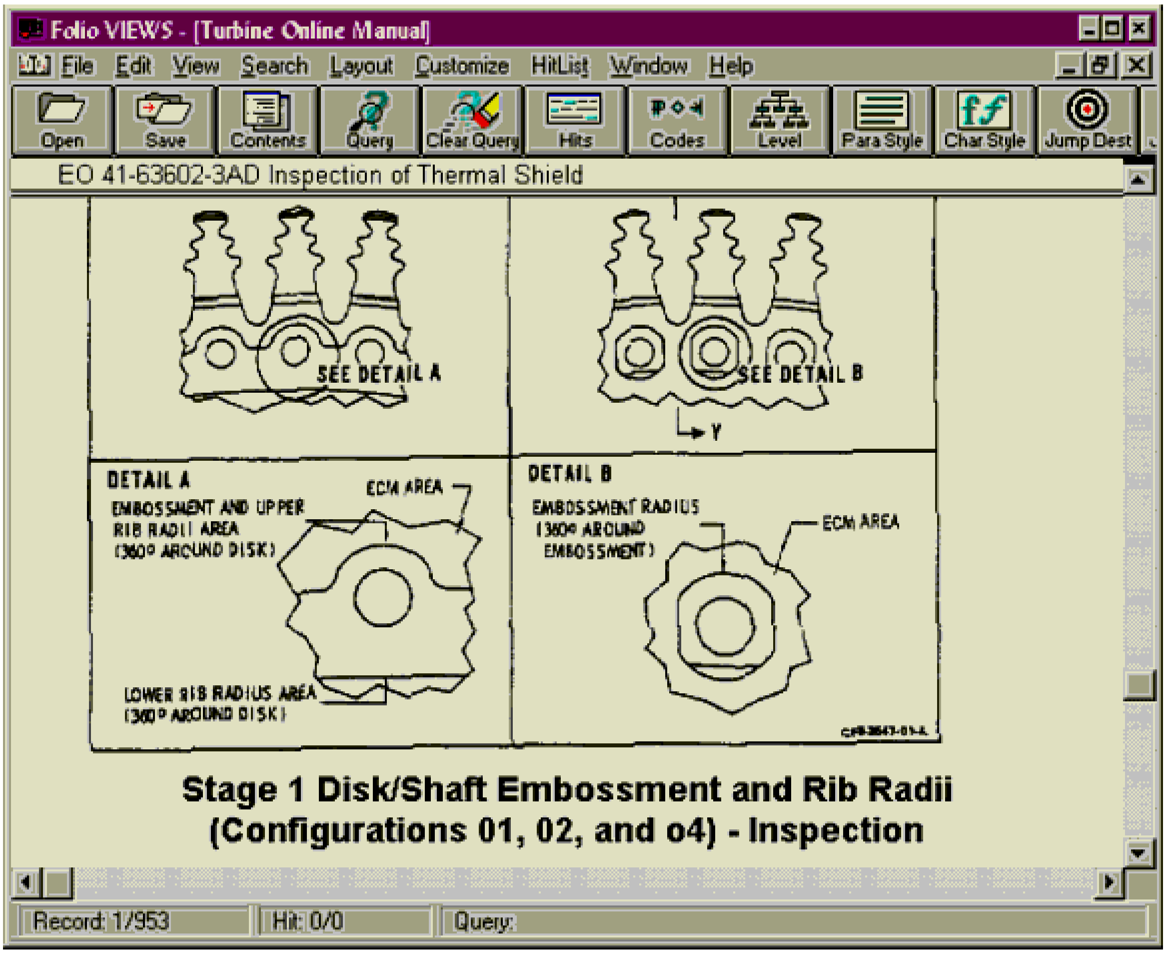


Figure 1.2 Example Screens from the Digital Engine Manual

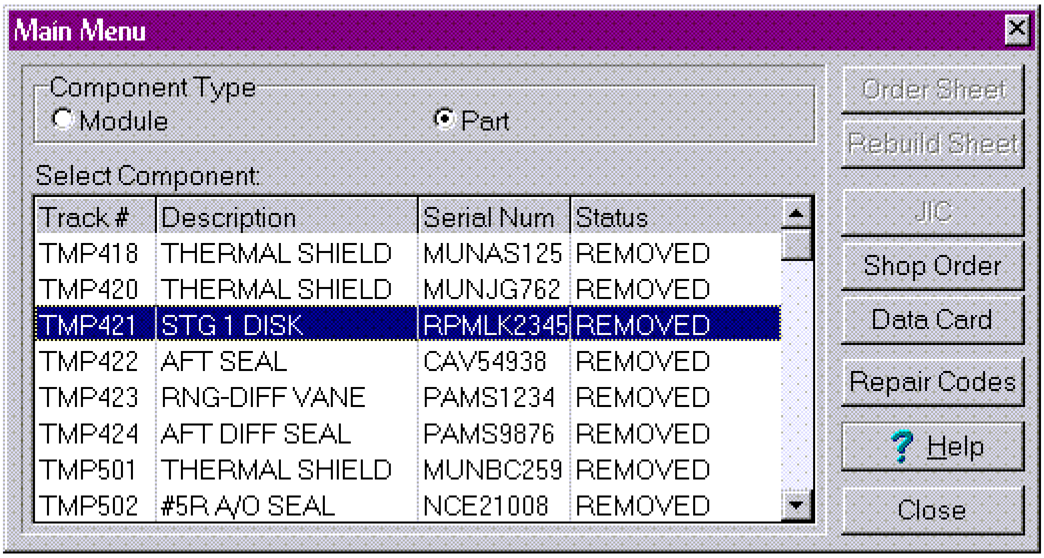


Figure 1.3 TRACS Main Menu

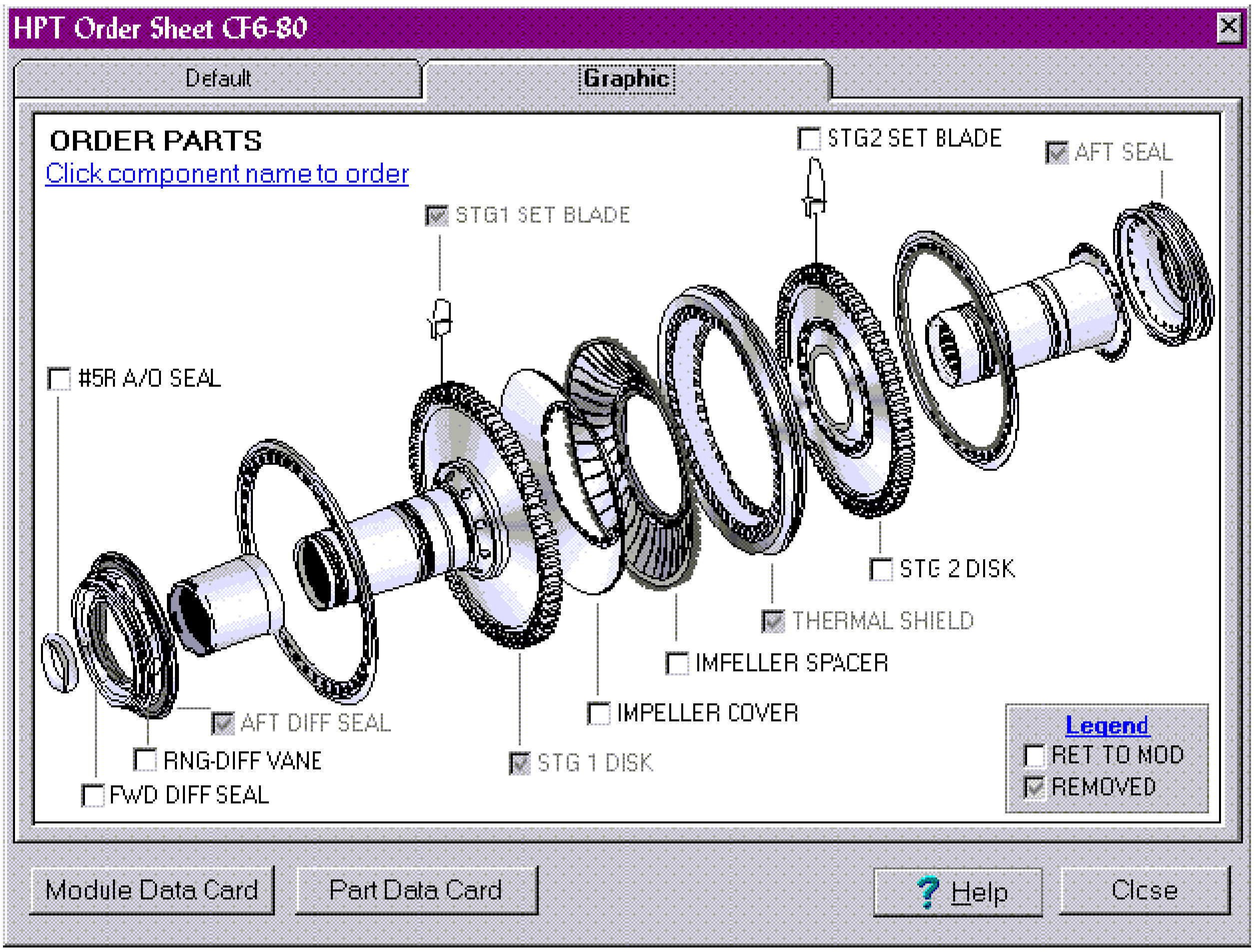


Figure 1.4 High-Pressure Turbine Module Order Screen

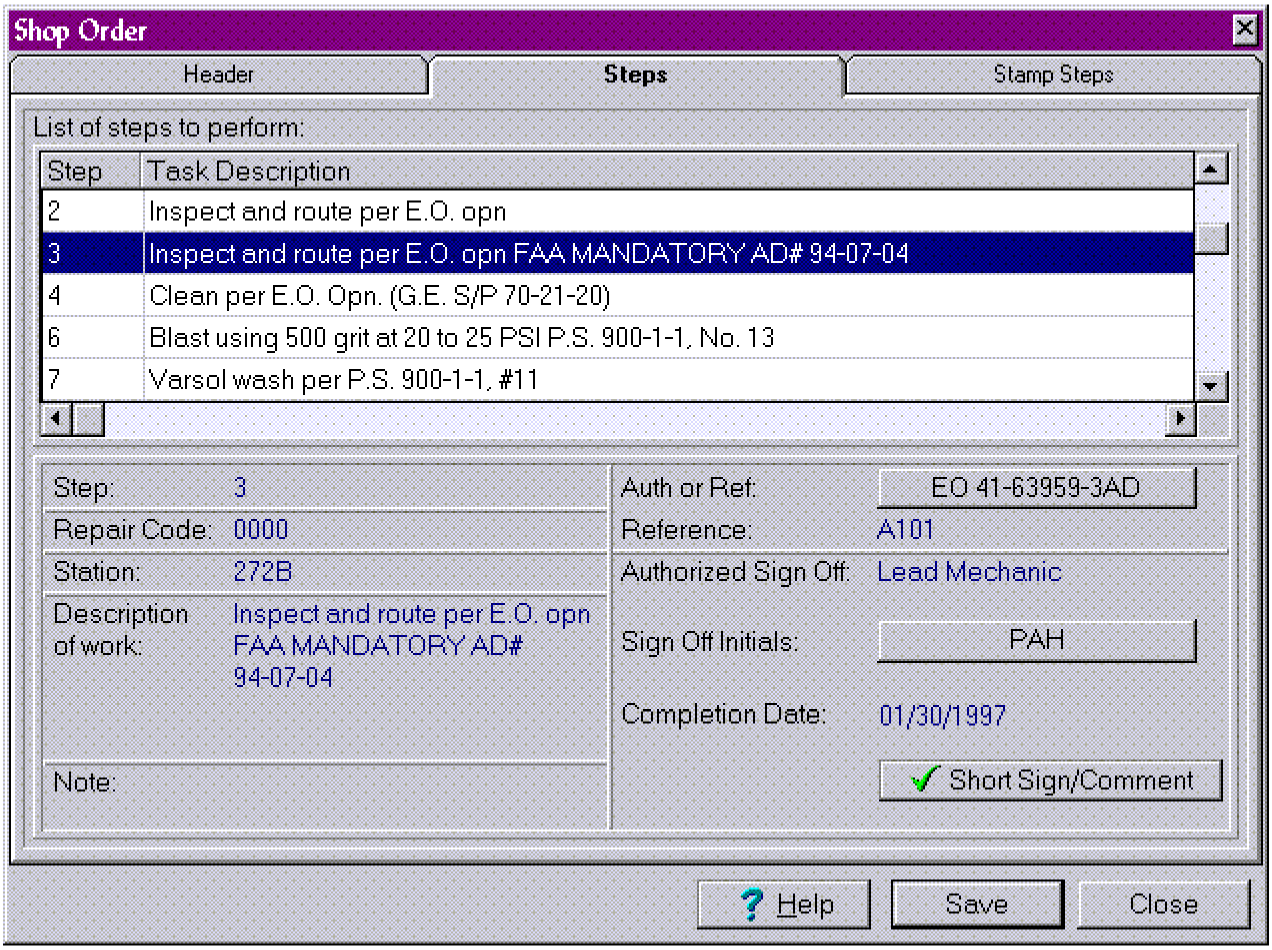


Figure 1.5 Shop Order with Active Repair Steps

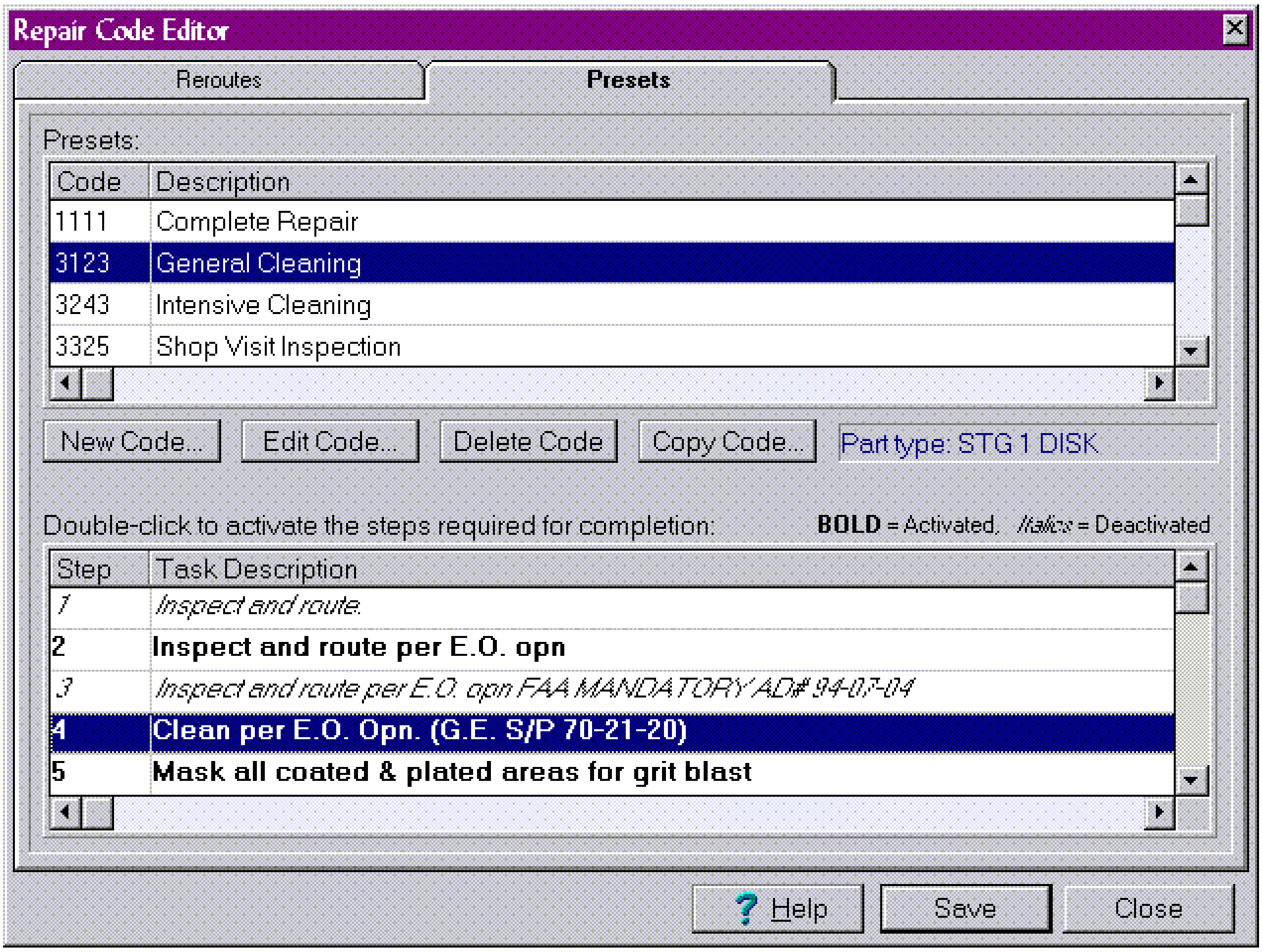


Figure 1.6 Repair Code Editor: Presets

1.4 PROTOTYPE EVALUATION

The evaluation of the software took place from December 12 through December 18, 1996. On the first day of the evaluation, the morning was spent demonstrating the features of the software to the technicians, and providing them with time to get familiar with the hardware and software. The software was provided on a Fujitsu Stylistic 500 pen computer, which contained a 50MHz Intel 486/DX processor. One pen computer with pen, keyboard, carrying-case, and portable printer was given to the technicians for evaluation over the next four days. Technicians were asked to use the software for a period of one or two hours during the course of a normal workday, and simulate an actual repair of a module and parts.

Short evaluation forms were completed after the first morning of the demonstration to get initial impressions of the software usability and functionality. Longer evaluation forms were left with the technicians for completion after they had finished the simulation of repairing a part. A verbal feedback session was conducted on the morning of December 18 in order to capture information that would not be elicited on evaluation forms. The session was taped with the permission of all present at the meeting. The forms and the hardware were picked up on the afternoon of December 18.

1.4.1 Results and Discussion

Both written and verbal feedback was collected concerning the usefulness and usability of the software. Evaluations also included comments about the pen computer hardware. The following sections describe the feedback received from technicians and work center personnel.

Usability Analysis

It should be noted that the present research should be considered a case study, since only one shop was chosen for the design of the prototype, and within the shop only one representative of a particular job class could participate in the evaluation. This was due to real world constraints on production and turnaround time for the technicians. Even with this limitation, results of the evaluations were very encouraging.

Results from the preliminary evaluation form were divided into two categories: Work Center responses and Mechanic/Lead Mechanic/Inspector responses. This was due to the fact that the task analysis and the software were focused primarily on the mechanics, lead mechanics, and inspectors. Functions for the work center personnel were only included if they related directly to the other jobs. Therefore, many of the work domains for the work center personnel were not represented in the software and many questions on the survey did not apply to their job. Responses from this group should be considered with caution.

All questions were rated on a scale of 1 to 5, with 1 being strongly disagree, and 5 being strongly agree. All questions (except three, which were reverse coded) were worded in such a way that a response closer to 5 was a positive evaluation. For example, the first question was "Having reference information (Engine Manuals, EOs) available within the program would make routing parts easier."

Results of the initial evaluation and final evaluation are presented in Figure 1.7. Responses indicate that in most domains, evaluation of the software was highly positive. This is demonstrated by the fact that average responses to domain questions were well above the midpoint of the scale in the majority of the domains.

In Figure 1.7 the leftmost pair of bars show the results of the evaluation given immediately after the demonstration. The remaining pairs represent domains of the final evaluation, which occurred one week later. Lighter colored bars are average responses from the work center personnel, and darker colored bars are average responses from the technicians. The domains of the final evaluation were:

- Utility Impressions - the "usefulness" of the software.
- Hardware - the usefulness and usability of the pen computer in relation to the job at hand.
- Productivity Enhancement - the ability for the software to meet objectives and increase personal productivity.
- Speed/Look and Feel - the time it takes to move between areas of the program, and the aesthetic design.
- Usability - the ease with which individual functions and screens are used.

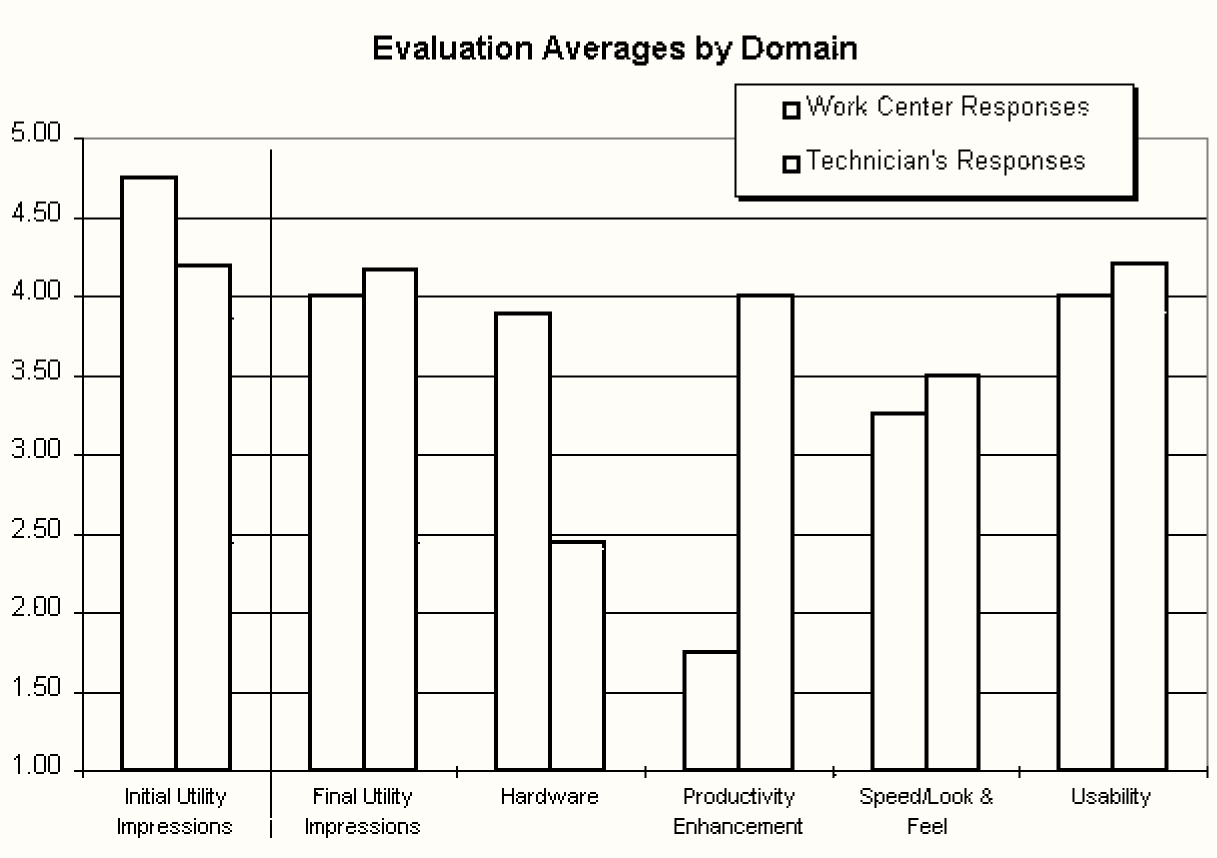


Figure 1.7 Results of the Evaluations

Results indicate that users found the software to be highly useful and usable. The only areas in which the average response fell below the midpoint (average) of the scale were the technicians' ratings of *hardware* and the work center personnel's ratings of *productivity enhancement*. Because verbal feedback explained both of the results, these issues will be addressed in the verbal feedback section.

These results are clearly positive and indicate that participants overwhelmingly viewed the software as an improvement to their current method of completing work.

Verbal Feedback

According to the surveys, technicians rated the pen hardware poorly. The reason for this was discussed at length in the follow-up meeting. Technicians discovered that the handwriting recognition software was not able to understand their handwriting on many occasions. This is a common complaint about handwriting recognition, and studies have indicated that users become more proficient with practice. Given the brief span of time for evaluation, this result is predictable. Mechanics and inspectors both agreed that a better hardware solution would be a desktop or a laptop computer, since keyboard input is preferred. This group also made the comment that their jobs mostly occur in a single area or workspace, and that having to move back to a workbench to enter data would not be problematic.

It should be noted that the work center personnel gave a much better rating for the pen computer. This is because they tend to move around the work facility much more than inspectors or mechanics. They are responsible for locating parts and modules in various storage areas, and believed that the use of a pen computer would be helpful. However, they also noticed difficulty with handwriting recognition. The tentative conclusion from these results is that pen computing devices can be implemented successfully so long as the job requires high mobility, and the amount of handwriting recognition necessary for inputs in minimized.

Other comments expanded on the fact that TRACS was not specifically designed for the work center personnel. The researcher's focus was on the mechanic, lead mechanic, and inspector jobs. One comment pertained to the method of rerouting and saving routing work, which was seen to be especially useful and well implemented. The ability to point and click to sign off and stamp steps was seen as a great benefit. Some improvements suggested were the creation of a menu containing all of the process standards required for routing, and also a digital version of the workscope.

1.5 CONCLUSION

Overall, the development and testing of the prototype was viewed as a success. There are many issues to confront when moving from a prototype project to a real-world implementation. The most complex issue is the connection of many sources of data. Users receive information from at least 10-12 different databases or sources during the course of a normal workday. Creating links with this information, making sure it is current, and presenting it in a format that is usable is not an easy task. With the constant push toward reduced repair cycle times, these issues will continue to surface. Developing prototype software which attempts to address the issues is a good method of learning the difficulties associated with making the transition to a paperless workplace.

1.6 FUTURE STEPS

A great deal of interest was generated following the testing of the prototype, and Delta Air Lines is currently embarking on their own pilot project which implements many of the concepts identified and developed in the rotor shop. During the course of the work, other airlines were identified who are moving in similar directions.

In the coming year we are planning to present the results of this research to a number of industry conferences. Capitalizing on some of the ideas from the project, we are planning to do a benchmarking study to determine the extent to which airlines are implementing these types of technology in their maintenance environments. This will provide us a rich context to explore solutions to the complex problems associated with automation and information delivery, with the explicit intention of increasing safety in aviation maintenance and repair.

1.7 ACKNOWLEDGMENTS

The author would like to acknowledge the cooperation and support of the people of Delta Air Lines, who made this research possible. I would like to thank David Dorrough for initially promoting our ideas, as well as Doug Magee who provided us with much of the information we needed to finish the prototype. Delta's automation group provided us with ideas and feedback, and many others gave us critical data which made our job easier. A special note of thanks goes to all of the people of the Rotor Shop who took time away from work to help us design and test the software. They gave us the most valuable encouragement and guidance along the way.

We are deeply grateful for the financial and directional support of the FAA Office of Aviation Medicine, especially Dr. William Shepherd.

Thanks to all of the people who advised me on how to get started with the project. I must also commend the hard work of all members of the TRACS team, each of whom did an excellent job.

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Chapter 2
RE-PURPOSING THE SYSTEM FOR TRAINING OF AVIATION REGULATIONS (STAR) TO AID ON-THE-JOB TRAINING FOR AVIATION SAFETY INSPECTORS

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2.1 INTRODUCTION

This chapter traces the process of re-purposing a sophisticated CBT program -- the System for Training Aviation Regulations (STAR). The original application was built for students training to be Aviation Maintenance Technicians (AMTs). The new application has been repurposed to function as an On-the-Job-Training (OJT) aid for Aviation Safety Inspectors (ASIs). Three main issues addressed within this chapter are:

- How does one retain sophisticated training techniques in CBT while allowing one to modify the training program to fit a variety of training needs and audiences?
- How does one keep the training program current in technical domains where knowledge evolves rapidly and living documents are the norm?
- Can one design a program that grows with an individual as that individual matures into his or her job?

The first half of this chapter reviews the original STAR research program. Included in the summary are the theoretical motivation guiding the STAR approach and a discussion of three evaluation studies. The latter half of the chapter traces the transition of the STAR approach as it is repurposed to meet the needs of a new target group and the constraints and opportunities of a different training environment. A description of each of the learning environments in the new STAR for ASIs is also included within these sections. In light of the analysis of this transition, recommendations for handling the three flexibility issues outlined above are presented at the conclusion of the chapter.

2.2 STAR-AMT

The STAR project began in October 1994. In the first six months of the project a needs analysis was conducted and a prototype of STAR built. STAR then went through two evaluations. The first evaluation assessed the usability of the interface; the second assessed to what extent and in what areas STAR was useful as a training application. These evaluations are summarized briefly below. From the result of these formative evaluations the interface of STAR was modified and its content embellished. This concluded the first phase of the STAR project which formally ended in April 1996.

2.2.1 Target Audience

The target audience for the initial development of STAR consisted of Aviation Maintenance Technicians (AMTs) in training. They are students enrolled in a college or high school specializing in this area. Most of these students are new to aviation.

The FAA Part 147 training program for AMTs includes a course on aviation maintenance regulations and document research. Learning about the Federal Aviation Regulations (FARs) comprises a substantial portion of the course. Students tend to take this course early in their training program before they have had much general aviation experience. In addition, the material is dry, not intuitively organized, complex in presentation and content, and written in legalese. As a result students tend to take a mental nap when they get to this portion of the course, according to their instructors. Given their limited experience in aviation, they do not see the relevance of what they are studying. Students also tend to get bogged down in the details of the FAR passages, missing the big picture. Instructors have few tools to make the material more vibrant and meaningful, relying heavily on reading passages out of the FARs and discussing their content.

It is within this instructional environment that STAR was developed.

2.2.2 Theoretical Approach

This section, covering the theoretical approach to STAR, originally appeared in section 2.2 of Chapter 2 of the FAA/AAM Phase 6 Report.1 It is included here as a convenience to the reader. If you are familiar with the STAR chapter in the Phase 6 report or other publications about STAR you may skip this section.

Multiple Vantage Points to Complex Information

There are two aspects to information complexity that have bearing on the instructional process. One is the relative difficulty of an individual concept. The other is the volume of information. In order to state "I understand this concept," or to say "I am an expert in this domain," one needs to be able to integrate components of a concept or domain into a scheme that can readily be demonstrated to others. A key factor to demonstrating conceptual understanding is the ability to distinguish relevant from nonrelevant information. Conceptual schemes help to organize conceptual components and discern the difference between central and peripheral concepts. Taking multiple vantage points to a content area contributes to building conceptual schemes by providing overlapping information where the central themes tend to be repeated.

STAR-AMT is designed to help students acquire the "big picture" about what the FARs' role is in aviation. This is done through developing a conceptual scheme about how the FARs impact the daily tasks AMTs must perform and also what the AMT's role is with respect to complying with the FARs. This is accomplished, in part, by providing many vantage points to the same body of information. Experiencing complex material, repeatedly, under different circumstances provides multiple opportunities to gain a deep understanding of the subject.2 Each vantage point not only covers different aspects of the same material, but also reinforces different kinds of study skills. In this way, students are not only provided with multiple ways of viewing the information, but also with multiple opportunities to learn. In addition, information conveyed through one learning environment may best fit one student's style of learning, while the other learning environments fit other people's learning styles. Thus, more people benefit when multiple approaches to the subject are taken.

Learning in Context

Part of the difficulty in teaching the FARs is that students perceive the subject to be very dry. Indeed, some of the tasks expected of the students can be pretty tedious. However, there are many opportunities to convey the complexity and subtlety of the information in interesting ways. Telling "war stories" by AMTs currently out in the field is one way to make the material more interesting and meaningful to the student. Stories are well-suited for capturing tacit instructional knowledge, because storytelling is a more natural way for people to convey ill-specified practices.3

Another way to make the material more meaningful is to immerse the students in scenarios that confront them with "real world" decisions related to their jobs. By placing the application of the FARs in context, students have a much better chance of constructing for themselves a scheme4 for how the FARs operate functionally in aviation. When students are given the opportunity to learn in context, the concepts are acquired more rapidly, durably, and are more easily transferred to new situations.5 Both "storytelling" and "situated learning" through scenarios place the information to be learned in contexts that the student can more easily relate to and remember.

Media-Rich Presentations

Media-rich presentations are a third approach to making the subject of the FARs more interesting. Multimedia has other pedagogical advantages as well. According to Park and Hannafin,6 multiple, related representations improve both encoding and retrieval. Learning improves as the number of complementary stimuli used to represent learning content increases. For example, when concepts are encoded in both verbal and visual forms, they are retained in memory longer and are more easily accessed, because the two types of information complement each other in the activation, representation, and development of related information.7 Thus, complimentary information presented through multiple types of media is most favorable for conceptual retention.

2.2.3 The Learning Environments

STAR-AMT offers several different categories of learning environments: Overviews, Scenarios, Challenges, and Resources (Figure 2.1). Each category holds one or more learning modules for students to explore. Overviews show students how FARs are organized, how different parts are related to each other, and who is responsible for what aspects of those regulations. Scenarios are interactive stories that set students into true-to-life situations where they learn how and why they need to apply the regulations to their daily operations. Challenges are designed to provide students with a self-testing mechanism for assessing their knowledge of the material as well as to promote the integration of material covered in the other learning environments. Resources are comprehension aids such as a glossary. These aids provide "as-needed information" that can be explored independently or used in conjunction with other, more formal learning environments. Each learning environment could be a stand-alone application. Together they provide multiple vantage points for students to arrive at a deeper understanding of aviation regulations. For a complete description of each learning environment in STAR-AMT, refer to section 2.3 of Chapter 2 in FAA/AAM Phase 6 Report.1

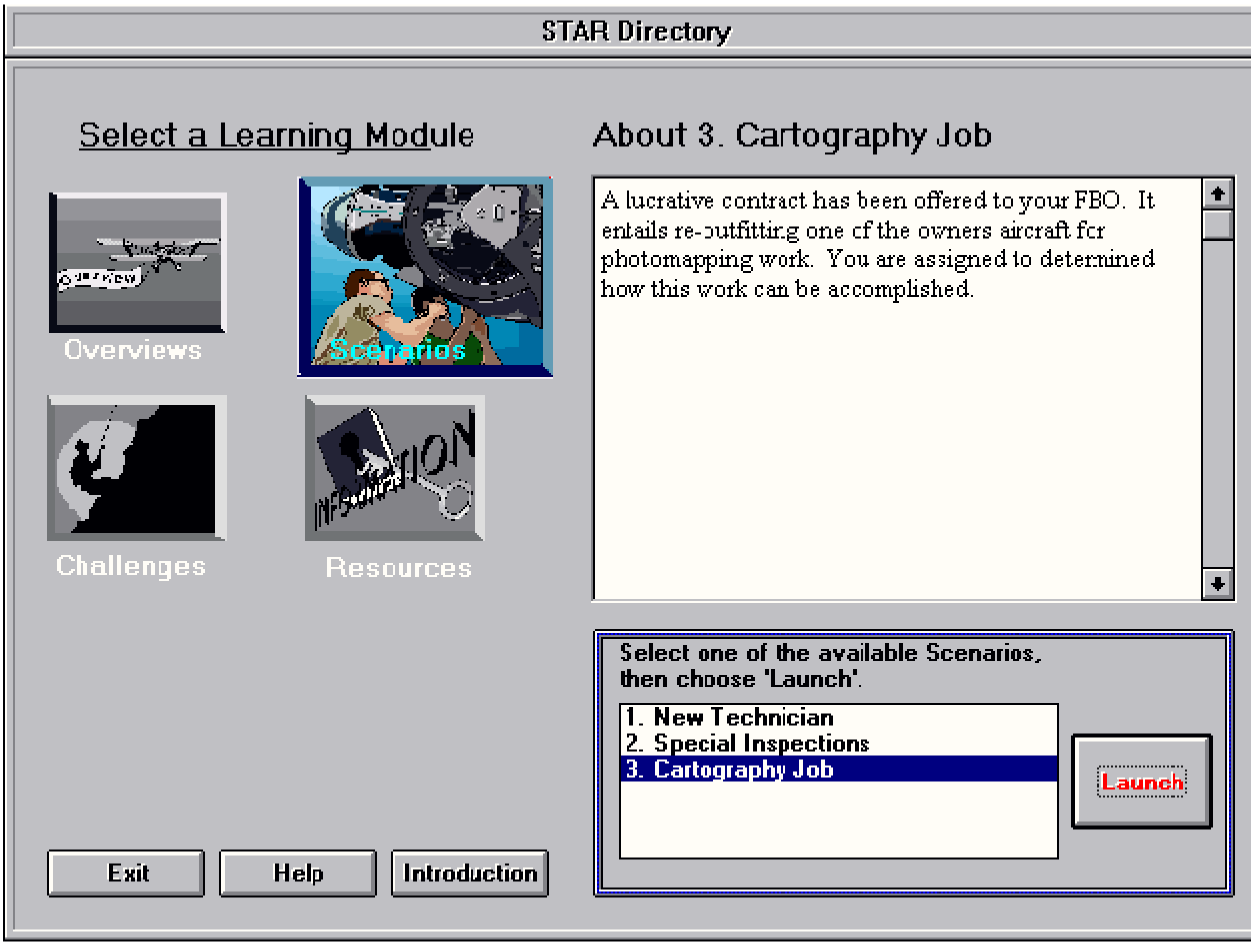

Figure 2.1 STAR-AMT Directory

2.2.4 The Evaluative Studies

STAR-AMT has been subjected to three formative evaluations by end users in the field. The first evaluation was conducted in July 1995, ten months into the project's start, and focused on usability issues such as navigation, screen design, and perceived conceptual understanding. At that time STAR-AMT consisted of an overview of FARs related to General Aviation Operating rules (Part 91), one scenario about "Special Inspections", a document browser, and a listing of informational media titles.

Evaluation 2 was conducted four months later in November. The second evaluation was designed to identify what kinds of learning would occur from the STAR-AMT experience. Evaluation 2 also covered usability issues because the subjects filled in the same assessment questionnaire that was administered to the first evaluation. At the time of the second evaluation most of the suggested design changes from the first evaluation had been incorporated into STAR-AMT and several modules had been added. A new scenario, New Technician, that addresses privileges and limitations of new AMTs, was added. The Glossary was also added. A new version of the browser had not been completed at the time of the second evaluation; consequently, review of the Document Browser was not part of the second evaluation. For a thorough discussion of the first and second evaluation see section 2.4 of Chapter 2 in FAA/AAM Phase 6 Report.1

Though the first two evaluations provide the research team with information about STAR-AMT's usability and teaching effectiveness, they provide no information about whether or not STAR-AMT was being used in training of AMTs and in what capacity STAR has been used.

The third evaluation, to be conducted in February 1997, will collect information about whether or not STAR-AMT is being used in the field and if so in what capacity. STAR-AMT has been distributed to over 1,000 individuals and groups in the aviation community through the dissemination of products resulting from the FAA/AAM research program since January of 1996. Those known to be actively involved in the training of AMTs will be contacted in February 1997. They were asked to shed light on the following areas:

a) Have they or their colleagues actively used STAR for aviation maintenance training?

b) If STAR is being used, in what capacity have they or their colleges used the system?

c) If STAR is not being used, why it is not being used?

An analysis of the results of this information will be presented at the **11th Annual Meeting** of the **FAA**/**AAM** Human Factors Issues in Aviation Maintenance (March 1997).

Summary

STAR-AMT represents a more open exploratory approach to training than the more lock-step approach most commonly seen in the training of procedural knowledge. In an open approach, students are provided with a mechanism for acquiring a global understanding of a domain; however, there is less control over the specifics of what is learned. As an individual builds a conceptual map, that individual will incorporate different details to support that conceptual map. Thus, while each individual will acquire an understanding for "the big picture," the details that support that global understanding will vary. In complex domains, the curricular goal should not be that everyone knows the same thing, but rather that everyone supports the same general conceptual scheme of the domain with some variation in the details of their common understanding. This approach to knowledge acquisition supports and perpetuates communication within the knowledge community. Common domain themes support the tacit assumptions of the "truths of the domain" under which everyone is operating, while variation in details promotes ongoing discussion of and refinement of the community's collective knowledge. As long as the conceptual scheme is sound, and the details incorporated within the scheme supportive, then the variation in the details of knowledge between individuals is actually a strength rather than a weakness within the community.

2.3 THE NEW CHALLENGE: RE-PURPOSING STAR FOR ASIs

In April 1996, the STAR research team began to explore how STAR could be reconfigured to address the On-the-Job Training (OJT) needs of Aviation Safety Inspectors (ASIs). The discussion below describes the characteristics of the new target audience and their working environment. This is followed by a description of the new STAR application. A comparison between the pure training version of STAR-AMT and the new on-the-job training version of STAR-ASI is made.

2.3.1 New Target Audience; New Working Environment

This is a very different target user group in a very different training environment. ASIs are experienced. Where the AMTs were relatively young naive students new to aviation, ASIs begin their inspection career after ten to fifteen years of experience in the field. ASIs are older. The average age of an ASI is 45. They are specialists in their field and they are also enforcers of the regulations. They must have an intimate understanding of the intent of the regulations and it is assumed that they do.

Another significant difference between ASIs and AMT students is that ASIs are working. Their primary concern is doing their job. Built into the job is an extensive On-the-Job Training (OJT) program for both veterans and new recruits. Flight Standards has a well established mentoring program for all new recruits, and each new recruit must pass an exam for each inspection before (s)he can perform that inspection unsupervised. Integral to the general atmosphere of pride among the ASI community is a collective consciousness of how one should conduct oneself as an ASI. Throughout the halls of a Flight Standards Division Office, one is aware of an ongoing discussion about the nuances of the FARs and regulatory procedures. This collective consciousness keeps regulatory conduct in the forefront and is vital to the overall health of the community.

Despite the extensive OJT program, there are problems. ASIs are expected to handle all types of inspections for all types of aircraft, not just their area of expertise. Veterans often feel hard-pressed to keep up with the field. It is easy to become rusty on inspections they do not do frequently. New recruits are busy learning through work. Because of extensive travel associated with the job, mentors are often not available to new recruits for consultation.

There are frequent complaints of not being able to keep track of documents and forms. In addition, most of the documents, including FARs, are living documents required to leave a historic trail of regulation changes embedded in the document itself. Technical orders, for example, specify exactly what an ASI must cover for any given inspection. These documents are what the new recruits are expected to reference when learning the steps of an inspection. Because of the legacy data, following these manuals is cumbersome.

OJT aids for new recruits seem to be developed ad hoc. Since each Order and OJT manual has been authored by different groups, with no apparent coordination, similar inspections have different emphases depending on the writers. Clearly, a coordinated effort in development of OJT curriculum would benefit the OJT program. STAR-ASI is a first attempt to provide a platform capable of supporting a coordinated OJT curriculum development.

2.3.2 Description of STAR-ASI

Two inspections were chosen as curricular samples for developing the STAR-ASI prototype: the Cabin En Route Inspection and the A&P Inspection. The Cabin En Route Inspection checks aircraft cabin equipment as well as the competency of the flight attendants while performing their duties during a flight. It is a long involved procedure demanding a significant amount of interaction with both the flight crew and the flight attendants. It is also a very public inspection procedure. Passengers can readily observe the inspectors conduct as well as the fight attendants. The A & P inspection checks the knowledge, training and performance of an AMT. It is a small inspection usually coordinated with other inspections within a fixed based operation or similar facility.

STAR for ASIs is composed of the same general components as the STAR program for AMTs. Three of the learning environments - scenarios, resources and challenges - are similar functionally, with new content simply replacing old content. A new learning environment, Task Flow Charts, has been implemented in place of the Overview learning environment. Below is a description of each of the learning environments.

Inspection Task Flow Charts

Each inspection is considered to be a task (Figure 2.2). For their OJT, the airworthiness group has developed task flow charts that show the logical steps for each inspection task, including decision points (e.g., Has a FAR been violated?). By simply implementing these flow charts on the computer, the STAR team has been able to create an interactive version of that representation. Now a new recruit not only has a visual representation of each inspection procedure, but also can investigate each step in the procedure.

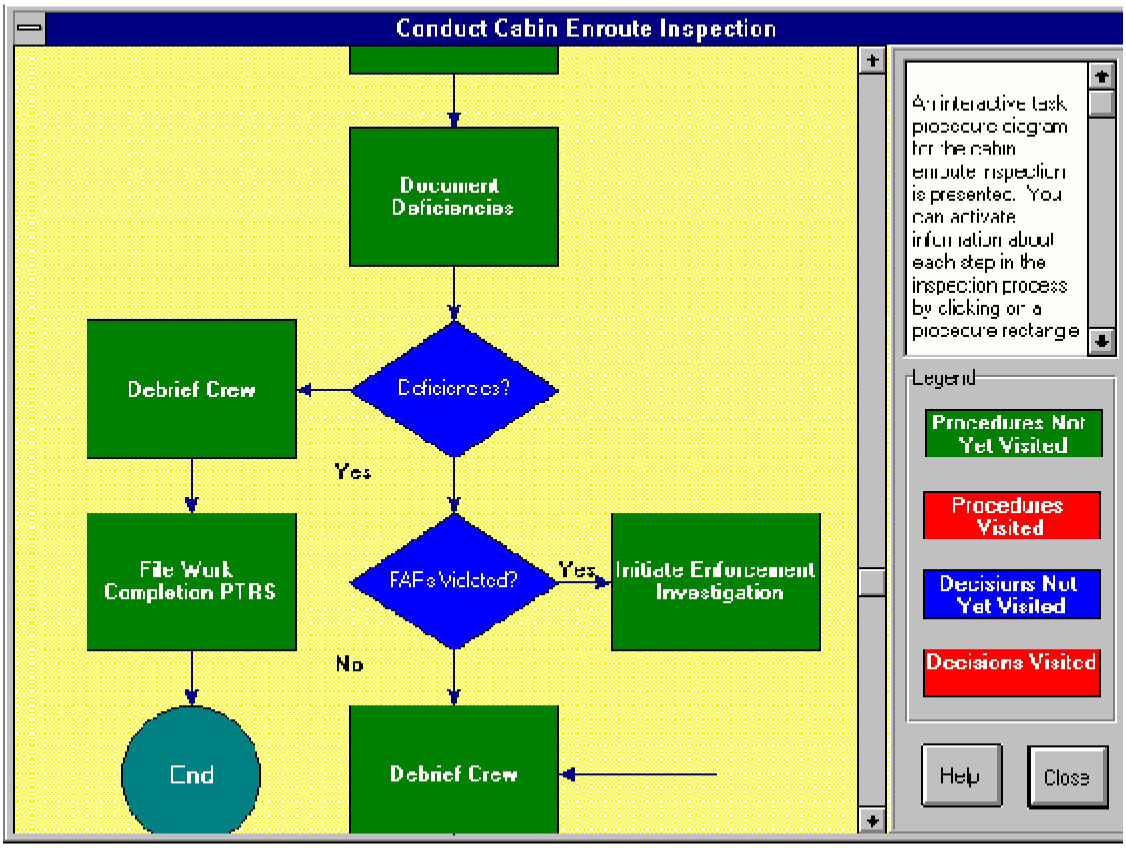

Figure 2.2 Task Flow Chart

Informational media is the most common approach for conveying salient points to the ASI on any given step in an inspection procedure (Figure 2.3). The Informational media display provides graphic, video, audio and text capabilities that can be interwoven to highlight important points an ASI should understand while conducting a particular inspection. For example, when an ASI clicks on an inspection procedure step such as "Initiate Investigative Report," a typical informational media piece may show a sample form, describe under what conditions the form should be used, and how it should be filled out. Within the same informational piece relevant documents, such as sections of Orders and FARs, are accessible with a press of a button. In another instance, a video may depict appropriate conduct during a delicate point in an inspection. For instance a video might be appropriate to depict how to approach the operator when a violation is discovered.

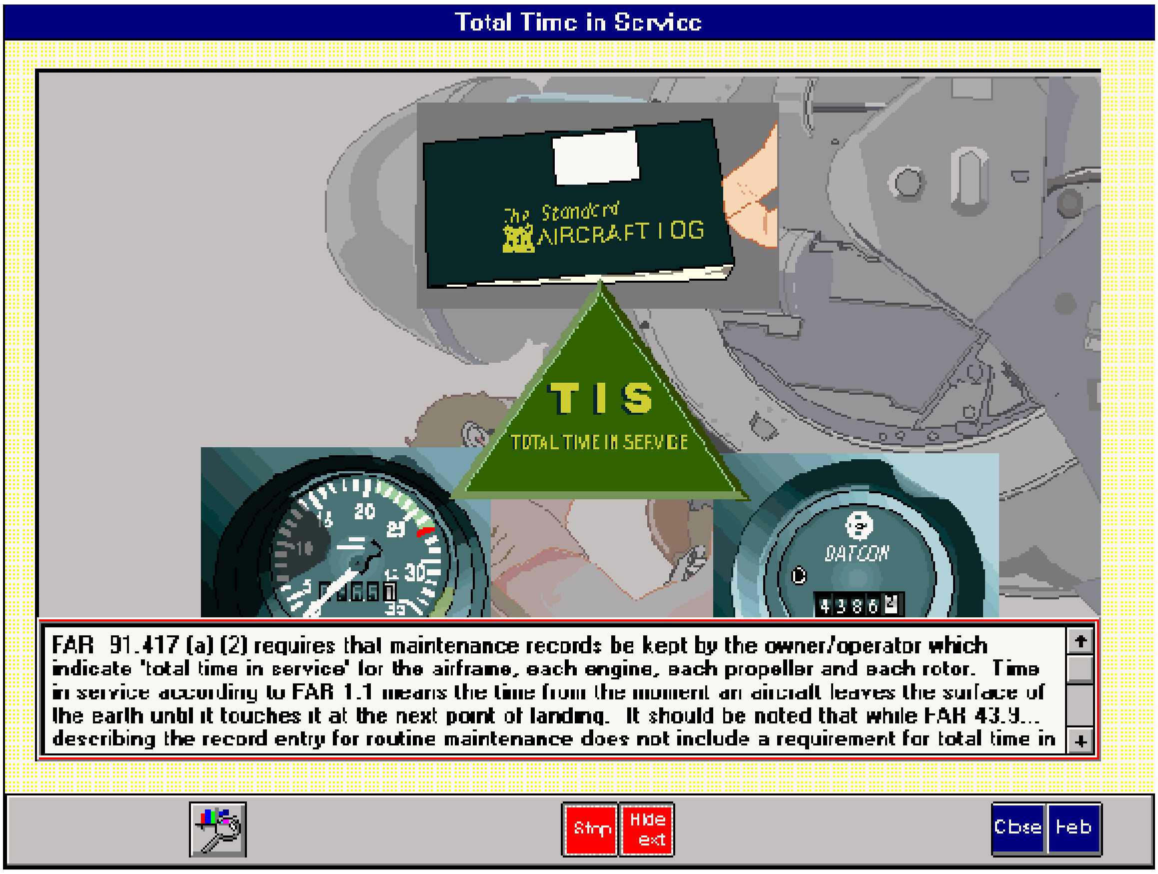

Figure 2.3 Informational Media

All other learning environments can be launched from a step in a task flow chart. Depending on the instructional objective, one has the option to ask a quiz question, show what a form looks like, reference a term in the glossary, comment on what an inspector's responsibilities are, or create a mini-scenario. Task Flow Charts give each inspection procedure a structure; the dynamic nature of the computer provides informational depth to that visual structure.

Scenarios

Scenarios are essentially interactive stories (Figure 2.4). In the opening scene of each scenario, ASIs are presented an ambiguous situation where several actions are possible. They are asked a question about what they should do and are presented with several actions that they could take. Each scene is portrayed through a graphic picture or photograph and the new situation is told through text and narration. The graphic picture sets the visual scene and the narration tells the story.

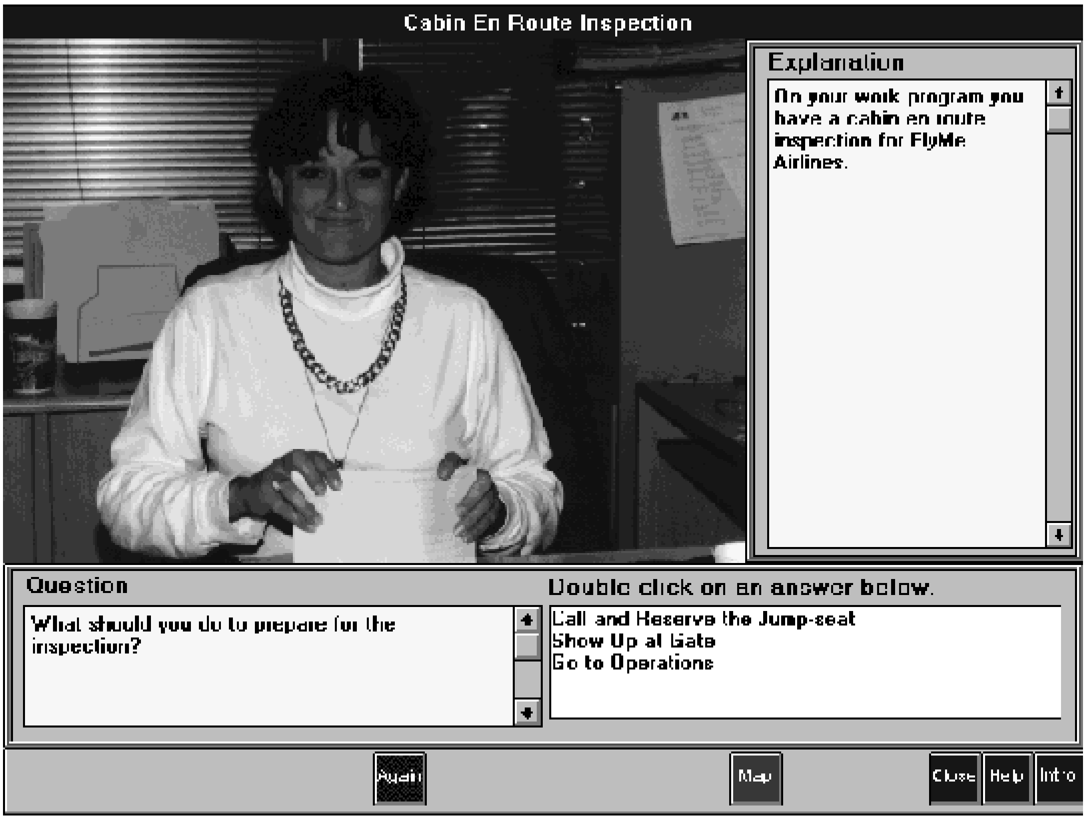

Figure 2.4 Scenario

Once an ASI chooses an answer, a new scene in the scenario is presented. The new scene reveals, through commentary and animation, the consequences of the action chosen and the rationale for why the ASI should or should not have made that choice. The ASI is then asked a new question and presented with new options until (s)he reach the end of that story line in the scenario. ASIs may access a map to help them navigate through the scenario. As an ASI moves from one scene to the next, the map updates to reflect the ASI's progress.

One noted difference between the scenarios in STAR and more traditional CBT is the idea that, in complex situations, there are no definitively right or wrong answers. Understanding why an action may be wrong is as important as knowing what is right. To get the most out of each scenario, ASIs are encouraged to explore all the story lines (or paths). By exploring all the paths, ASIs acquire a deeper understanding of the situation and of the subtle distinctions they need to make to comprehend fully the intent of the regulations. In this sense, there is no right answer, only deeper understanding.

Scenarios can be stand alone or attached to a step in a task procedure. Stand-alone scenarios are large multi-branching stories providing many salient points to a complex situation. Scenarios embedded within a task step are small -- usually making one central point within a specific situation. These mini-scenarios are useful when one needs to place a question within a context. Mini-scenarios are also useful when one needs a rich media format for presenting several different types of information to the user. For example, one may need to display several forms and give several types of background information to the user before they are able to answer the question presented. The scenario format provides such presentation flexibility.

Resources

Resources are comprehension aids such as a glossary. These aids provide as-needed information that can be explored in its own right or used in conjunction with other, more formal learning environments. There are three modules in the resource learning environment. The document browser is designed to provide searching and viewing documents in their entirety. It has full-text searching capabilities both within and among documents.

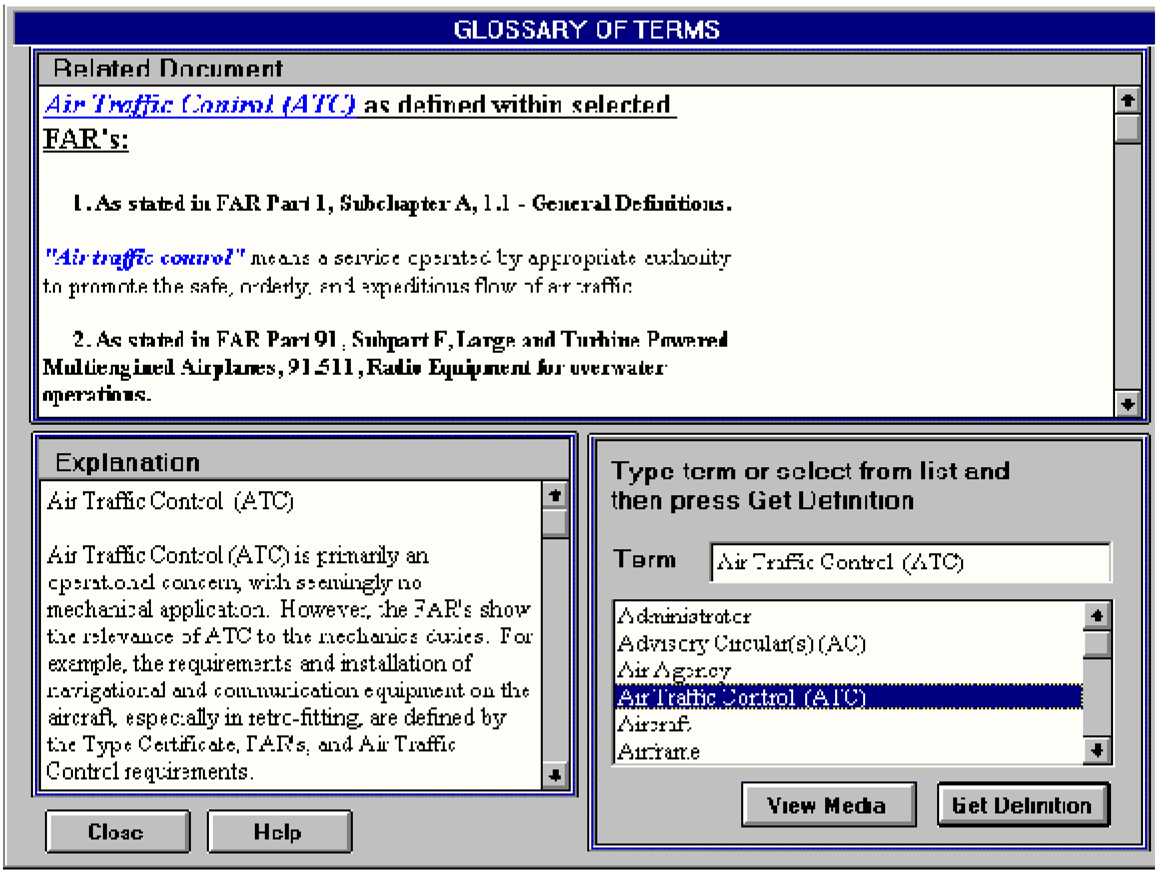

Figure 2.5 The Glossary

The glossary (Figure 2.5) defines and exemplifies commonly found terms in the FARs. Associated with each term are exemplars of how the term is used in a FAR passage as well as an explanation describing how the term is commonly used in the field. Where appropriate, graphics are provided that enhance the meaning of the term.

Challenges

Challenges are designed to provide ASIs with a self testing mechanism for assessing their knowledge of the material as well as to promote the integration of material covered in the other learning environments. Challenges can vary in complexity (Figure 2.6). They can be of the "self-test quiz" variety, composed of true/false, matching or multiple choice questions, where ASIs practice quick responses to specific facts; or they can be essay questions - where ASIs are asked to reflect on the intent of the regulations and how they are applied to inspection procedures. Associated with most challenge questions are informational media explaining the rational for the correct answer to each question.

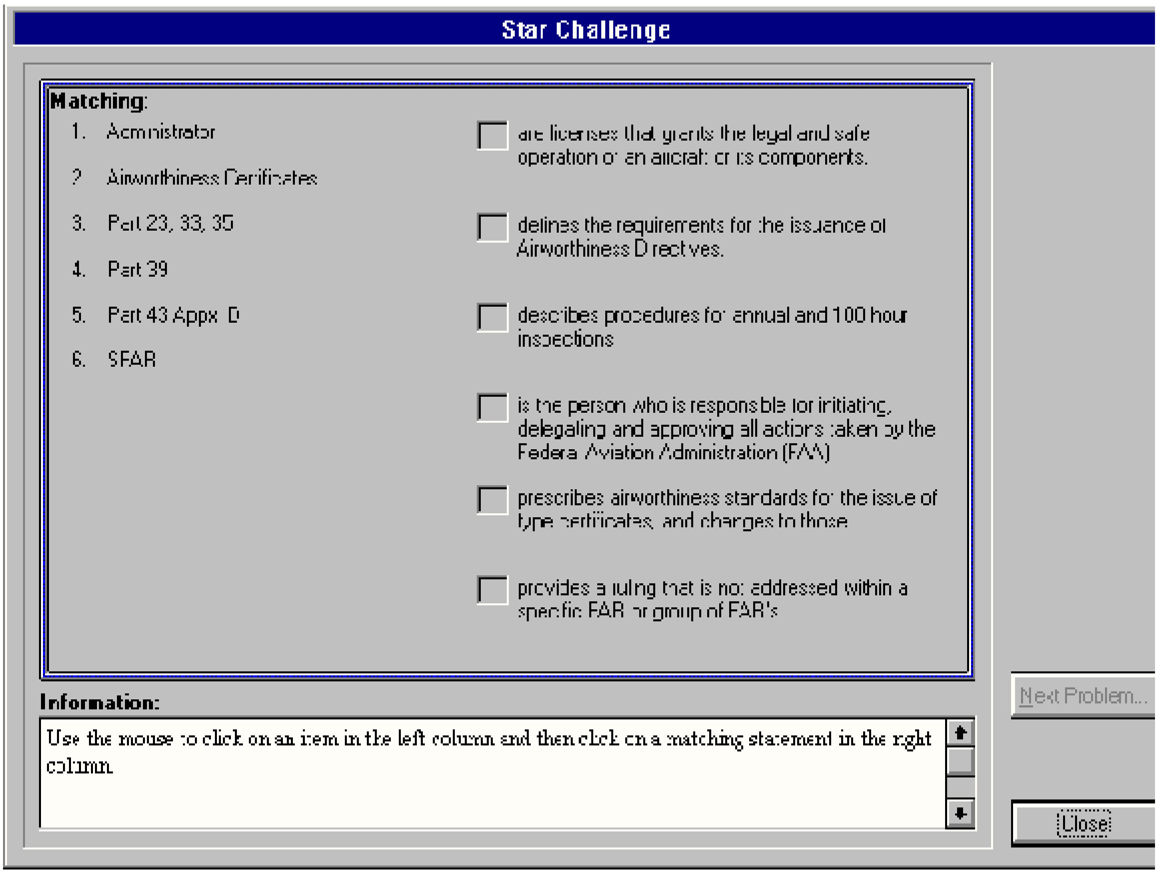

Figure 2.6 Challenges

The challenge learning environment is a stand-alone system that can be accessed from the STAR directory. When accessed through this route the ASI can answer each question in turn. After the last question all the true/false, matching, and multiple choice questions are tallied and a score provided to the user. The questions are then reset to try again. At any time the user can leave the challenge learning environment. Their progress is recorded so they can return to where they last left off. Individual challenge questions can also be launched from within the task learning environment. Thus at any point in a procedure, an ASI may receive a "pop quiz" question about a specific procedural step. Associated with each quiz question is commentary explaining the correct answer.

2.3.3 The Emphasis

Interactive Task flow charts have become the center piece of STAR for ASIs whereas scenarios were the centerpiece of the AMT course. Because inspections are so procedurally oriented, task flow charts best represent what an inspector needs to consider when doing a particular inspection. Interactive Task Flow charts have certain curricular advantages. They can function as a reference, as well as a guide. In the simplest instance, a step may just have commentary or it may have sample forms available to remind ASIs of what the forms look like and for what purpose they are used. Sections of Orders and FARs relevant to that step (and only those sections) are attached for the ASIs perusal. Where appropriate, the document is structured and highlighted to reveal its most salient points. Legacy data is removed for clarity. These simple features allow ASIs to review the most salient points and information associated with any given inspection.

Based on task analysis and numerous discussions with ASIs, the team decided that scenarios are best suited for situations where:

- there is a significant amount of interaction between people,
- there are several plausible ways a person can respond to a situation,
- individuals must draw upon a significant amount of their resources or understanding of the situation in order to make the best decision, and
- choosing a wrong answer does not necessarily terminate the story.

The STAR team found that scenarios were much easier to generate for maintenance than inspections. Part of this may have been due to the characteristics of the people who provided the scenarios; part of this had to do with the nature of the two domains. Stories generated for maintenance tended to be about a job that needed to be done and what considerations needed to be made in order to complete the job legally. Many interesting situations could be woven from doing a major repair or conducting a 100 hour maintenance inspection. The storytellers being instructors was another advantage. Part of their job involves weaving stories to make salient points about aviation concepts. Inspectors are more procedurally oriented. They can easily generate "what if" questions (e.g. What if the captain does not have his medical certificate? What if the first aid kit is not sealed?) but often these questions terminate the story with a violation. The highly procedural and primarily linear nature of inspections make weaving an interesting and authentic story more difficult.

Some inspections are just not involved enough to warrant writing a "story" about them. For example, of the two inspections the STAR team used as curricular samples, the Cabin En Route Inspection had the subtlety and complexity to warrant generating a scenario. The A & P inspection, however, did not. A common practice for an ASI is to perform several small inspections together during a site visit. For smaller inspections, scenarios can be handled a couple of ways. They could be broken up into mini scenarios that address a single situation and launched directly from a step in the task flow chart. Here the ability to present a complex situation in a single scene is retained without the added burden of linking several scenes together into a story line. Another option is to create scenarios about different types of site visits where several inspections are conducted. Each individual inspection may have only one salient point to make, but taken together the scenario is able to reveal the subtlety and complexity of the situation.

2.3.4 From Training Aid to Job Aid

STAR-AMT has been designed to be a training resource to complement instruction rather than to replace it. Any part of the program could be used within the context of a lecture presentation, as a reference or for independent study. Even the scenarios were designed to be explored rather than just stepped through. The structure of STAR is flexible to complement different styles of teaching. While there are many strengths to this approach, there are also some weaknesses. Independent exploration encourages self-directed learning, but at a cost of homogeneity of learning across individuals. While students are exposed to the general body of knowledge from several different vantage points, there is less control over the particular information that an individual acquires. As a job aid, however, this browser-oriented design approach is advantageous.

For STAR-AMT, resources augment and support training; for STAR-ASI, the emphasis is reversed - training augments and supports resources.8 Even in the context of OJT, the primary activity and concern of each ASI is having the right information at the right time to do his or her job well. Sometimes that may be learning how to conduct oneself during an inspection; other times it may be reminding the ASI which forms are needed for a particular inspection. In either case, STAR is designed to handle both needs. Task flow charts, for example, organize the information into a logical structure.

This structure can be used in several ways, depending on the experience of the user and his or her present needs. For a new recruit, the flow chart is a training aid that he or she can step through, see the organization of the inspection, quiz him- or herself, look up terms, or read relevant documentation; he or she can view sample forms and review how and to what purpose they are used. A veteran can review the steps of an inspection not done in a while before venturing out into the field. Or they might use it purely as a reference to look up which form they are suppose to use or the meaning of that acronym they never really learned. Scenarios which target new recruits more than veterans might never be touched by veterans. However, a mentor might employ the scenarios as a vehicle for discussions with new recruits.

2.3.5 Keeping Current

In the working world where documents are living and policies change, it is vital to create a CBT that supports this environment. Information and training should be designed so that they can be updated and changed easily. This means a more compartmentalized approach. If a step in the flow chart is no longer relevant, only that part should be changed, not the whole structure. In situations where compartmentalization of information is difficult, as is the case of a long involved scenario, the content should not focus on particulars that are likely to change. Rather, themes such as ethical conduct or procedural issues should be addressed. How one debriefs an organization after the completion of an inspection, for example, addresses an important theme about conduct that effects all inspections and whose message is unlikely to change over time.

Living documents, especially if they are expected to retain legacy data, can be difficult to maintain. It is this kind of information that will date a training system. Electronic publishing techniques could help maintain this kind of information. Electronic publishing structures textual information for different views so that the most relevant points are accessible for a particular audience. For example, legacy data can be hidden behind hypertext references. The history of the document is preserved but it does not obstruct the presentation of the most recent version of the document for training or review.

One simple mechanism for disambiguating the tangles of information that an ASI must sort through is to present just the sections of FARs and Orders they need for any given step in a procedure. The challenge comes when these references need to be updated. FARs, for instance, are updated every two weeks. Full text search found in electronic publishing may alleviate this problem. A query can be written to access the relevant pieces of information from the total document and display them within the context of the training program. Theoretically, one should be able to update the total document without effecting the query into that document. Of course, the success of this approach is only as good as the query that can be written and the extent of changes to any given document. Two many or extensive changes could disable the query system.

The last point is to empower the working community to augment its training/job aid. Like living documents, the culture of a work community changes. Training and Job aids should be sensitive to this and support it. For example, if STAR-ASI were to be installed on an intranet, the task flow chart learning environment could incorporate a comment box associated for each step in a procedure. If, for instance, a veteran wants to amend an "official" comment of a particular step, he or she can add his or her comment to the comment box for that step. His or her comment will be available to others in the office. A procedure for changing or updating the official comment could be provided. A mechanism for archiving comments each month is another possibility. The OJT becomes a repository for the collective conscience of the ASI community.

2.4 CONCLUSION

Four conclusions can be drawn from our experience with re-purposing the STAR program. First, it is much easier to build a resource that incorporates training than to build a trainer that some how metamorphoses into a job aid. Traditional training curriculum presents a logical progression of information, concepts and skills. Learners are expected to follow the curriculum in this logical sequence. Resources are also organized logically, but part of that organization accommodates the users need to answer specific questions quickly. The resource is designed to accommodate fast access to needed information, traditional CBT is not.

When intended as a job aid, training needs to be thought of as a type of resource. As a type of resource, it needs to be more self contained - functioning as a coach or advisor to the specific information the user is looking up. Training can still be organized into logical sequences of information, concepts, and skills, but it must also accommodate quick answers to specific questions. There are advantages to the "training as reference" approach. One need not worry about motivating the student. Users are motivated by virtue of the fact that they are asking the question. Because they are actively looking for an answer, their retention should be better as well.

Second, the system needs to be highly modular. In STAR, for instance, each learning environment (e.g. Resources, Scenarios, Challenges) is self contained, as is each learning module (e.g. the Glossary, the Cabin En Route Inspection Scenario, the A & P Task). One can swap out a training module, a learning environment, or a reference guide depending on one's training or job aiding needs. Third, applying a browser approach to interface design increases the options for how the system can be used. STAR's browser style interface gives the system the flexibility to be a presentation aid, a self paced tutor or a reference utility. It is not bound to a lockstep tutorial approach. Modularity and a browsing style interface give STAR maximum flexibility for accommodating different training and job aiding objectives. Finally, electronic publishing may offer some solutions for training systems that rely on living documents as the basis of their training, but the ongoing battle to keep training programs current will continue to be a battle for curriculum developers.

2.5 ACKNOWLEDGMENTS

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Chapter 3
SUPERVISORY TASK ANALYSIS: AIRCRAFT MAINTENANCE ENVIRONMENT

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3.1 INTRODUCTION

To improve the safety and quality of aircraft maintenance, it is important to understand the tasks and activities performed by those leaders and supervisors closest to work being performed. While detailed task analyses of the inspection and maintenance technicians are available,[1] the supervisory functions have been largely neglected. The supervisor has responsibilities for organization, effective communication, quality control as well as providing technical expertise whenever necessary. A task analysis of the supervisory function may lead to a better understanding of the requirements of this function which in turn may lead to job-aids that can support this function.

This study examined the tasks and activities of lead mechanics and foremen in two major aircraft maintenance facilities. The lead mechanics on routine and non-routine maintenance work were selected for study since their tasks tend to be fast paced, varied and comprehensive. These lead mechanics (LMs) act as a focal point carrying out the directives from their supervisor, coordinating and communicating with other LMs, and solving the needs and problems of their crew.

Are the difficulties that supervisors face found across the airline industry? If so, such difficulties may be used to identify some innovation or job aid that will alleviate or eliminate the problems. The result of this study is general recommendations to facilitate the leadership tasks and activities of first and second line supervisors within the aircraft maintenance environment.

3.2 METHODOLOGY

A task analysis technique was employed to understand the activities of the first and second line supervisors in the aircraft maintenance environment. There are a variety of methods available for conducting a task analysis, each with its own advantages and disadvantages. These methods include charting and network techniques, decomposition methods, hierarchical task analysis, link analysis, etc. Techniques for the collection of data for a task analysis include questionnaires, interviews (group and individual), work participation, observations, and diaries.[2] No one procedure is right for all cases, and generally a combination of data gathering techniques produces the best results by providing the flexibility to meet the conditions and constraints.

A hierarchical task analysis technique was used in this study, and the work involved was broken down into three majors steps. The first step was to become familiar with the environment, technologies, and characteristics of the job being analyzed. This was accomplished through informal familiarization site visits. The second step was the collection of the task data. The final step involved the organization and analysis of the data. The following sections will discuss each of these steps in detail.

3.2.1 Familiarization site visits

Familiarization site visits were conducted to observe various levels of supervision -- over three shifts and across several types of maintenance activities. The familiarization site visits were scheduled to start two hours before the shift change and continued until two hours after. Thus, in two visits, observations were made on all three shifts. When circumstances permitted, both the shift foreman and the lead mechanic were observed at the same time. In a majority of the time, however, resources had to be divided so that both the levels of supervision could be observed simultaneously. A concept of "shadowing" was used to observe and ask questions without interfering with normal activity. During the two familiarization visits, two common maintenance activities were observed: a letter check or heavy maintenance visit (HMV), and a service check.

In order to achieve an adequate cross section of aircraft maintenance supervisory tasks, two large certified repair station were selected over several smaller operations. The larger facilities afforded a broader spectrum of operational protocols and tasks. The following provides a brief description of each company.

Company 1

This company operates several certified repair station facilities throughout the domestic United States. The company and the maintenance groups work under an organized labor contract covering all maintenance positions except foreman and above. A review of the organization showed that the actual controlling supervisory role begins with the position of foreman, and not at the lead mechanic level. This separation is do primarily to the interpretations and precedents established by the labor contract. The lead mechanic is considered a working member of the AMT group, and as such his/her role was delegated to that of an overseer and councilor to the AMTs and facilitator and manpower coordinator for the foreman. The position above foreman was the operations manager who had overall responsibility for the production efforts of the hangar complexes (four production bays) operating with a total of fifteen bay managers. Each production bay's effort was controlled by a centralized work center located at hangar floor level adjacent to the associated hangar bay. The coordination and continuity of work flow was managed by a work center planner and work center clerk. Both parties answered to the foreman.

The facility is dedicated to supporting all aircraft series within a single type aircraft. The aircraft are processed to the HMV level, although general maintenance, modification, and repairs could be performed on any aircraft type within the company's fleet.

Company 2

Company 2 operates several certified repair station facilities throughout the domestic United States. Unlike Company 1, this organization does not operate under an organized labor contract. The organizational structure showed that the lead mechanic is considered an actual AMT supervisor. The lead mechanic directly assigns work to the specific AMTs. This assignment regime is based upon the AMT's experience, talents and skills. The foreman assigns the number of AMTs to the lead mechanic to complete assigned tasks.

The facility is certified to perform the letter check scheme of progressive maintenance and several lower order inspections upon multiple aircraft types. To manage the operation, a single shift foreman was assigned to each eight hour shift (except during a relief foreman's overlap). The foreman supervises nine to twelve aircraft skill lead mechanics and their crews. The shift foreman responds to a single (day shift) general foreman who is accountable for the overall facility operation. Lead mechanics are designated to monitor production, quality, and efficiency of their crew. In addition, the lead mechanics oversee and coordinate training.

3.2.2 Data Collection

For the purposes of data collection it was decided to focus on the aircraft maintenance foreman and lead mechanics within the first shift for Company 1, and within the first and second shifts for Company 2. This decision was made for the following reasons:

1. As previously mentioned, at Company 2 the aircraft maintenance Lead Mechanic had the primary responsibility for the aircraft and coordination with the Hydraulic and Avionics Lead Mechanics.

2. The second shift (1500-2300 hrs.) was exposed to a myriad of operational variables which include: (1) work turned over from previous shifts, (2) acquisition of new work, and (3) time constraints due to the need for aircraft availability.

3. The second shift had its own culture which in part reflected the culture of the first and third shifts.

4. The importance of observing the shift turnover between the identified supervisory levels was considered a critical task area.

The data gathering method selected for this research was a combination of diary and observation procedures. These methods were selected for several reasons. First, there was a large amount of data to collect (a minimum of eight working hours). Second, the supervisor's job is dynamic and unstructured. Third, the environments were noisy. Finally, first hand information could be obtained through demonstration of tasks and activities.

The foreman and a lead mechanic second shift were selected to be "shadowed." A meeting was held with the lead mechanic and foreman prior to the beginning of their shift, and the purpose of the research and the data gathering procedures which would be followed was explained. Every effort was made to not interfere with work activity. Questions concerning task procedures were asked during lulls in the work activities.

3.2.3 Organization and analysis

Once the diary of activities was obtained, it was analyzed and organized to categorize the various tasks and subtasks. The categorization facilitated a detailed task description which allowed for an analysis of the tasks with respect to supervisory skills. The following section gives a task description of the tasks and subtasks performed by the maintenance foreman and the lead mechanic.

3.3 TASK DESCRIPTIONS

The tasks for each supervisor are divided into three major categories: a) Administrative, which includes all tasks dealing with the required paperwork and information flow, b) Operations, or those tasks dealing with the movement, repair and/or modification of the aircraft, and c) Personnel, which includes those tasks that require the interaction of the supervisor with the AMTs (Figure 3.1). Companies 1 and 2 are different in many respects, and as such, some tasks described below are germane to only one company. However, conversations with other repair stations revealed that the tasks are generally common to supervisors throughout the airline industry. It is interesting to note that a majority of the Foreman's and Lead Mechanic's tasks involve the handling and processing of information. The following is a discussion of the tasks and activities by each level of supervision.

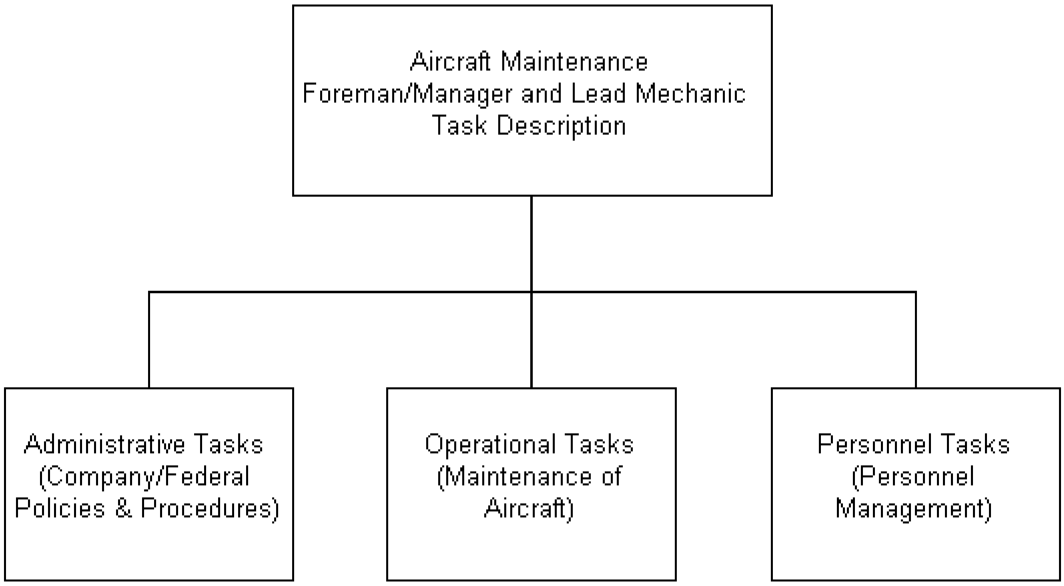

Figure 3.1 Task Categories for Supervisors

3.3.1 Foreman

The aircraft maintenance foremen are generally promoted to their positions from the ranks of lead mechanic. The technical knowledge and skills necessary to perform the supervisory functions were derived from experiences attained as a mechanic and were further refined in a wider scope as lead mechanic. Depending on the physical size of the maintenance facility, the areas of responsibilities included overseeing the AMTs and lead mechanics engaged in maintenance of a single aircraft to that of varied maintenance functions of multiple aircraft of various types and models. Aircraft delivery times were the major goal of all the second level supervisors observed, and the effective use of a work center and supporting personnel provided the supervisors with the monitoring and management tools necessary for the effective control of the maintenance activities towards that end.

Administration

Administrative tasks involve the management of paper work, information, and office related activities performed by the foreman. Although the work varies from day to day, the administrative tasks encompass a myriad of computer (electronic) paperwork and physical activities through a shift. The category of administrative related tasks include eleven major tasks: 1) process aircraft maintenance alerts, hangar maintenance alerts and other general information, 2) post crew assignments, 3) process various logs, 4) report to general foreman, 5) participate in shift meetings, 6) assume shift/hangar manager tasks as required, 7) assign tasks to lead mechanics, 8) receive and perform tasks from management, 9) approve payroll, 10) monitor compliance with standards and procedures, and 11) perform miscellaneous office tasks (Section 3.9.1). The following is a brief description of the tasks.

Process aircraft maintenance alerts, hangar maintenance alerts and other general information

Aircraft Maintenance Alerts (AMAs) and Hangar Maintenance Alerts (HMAs) contain critical information pertaining to the maintenance and hangar operations. They are a result of maintenance information received from several sources, both internally and externally (FAA, NTSB, aircraft and engine manufacturers, and other air agencies). This information may or may not be relevant to the specific work area to which the supervisor is currently assigned, but it is considered required reading by all supervisors. This information, in addition to being posted for required reading by all maintenance personnel, may also be presented in a briefing format to assigned lead mechanic and AMTs (especially when the information affects the groups activities).

Post crew assignments

The supervisor updates, maintains, and reviews a current list of lead mechanics and AMTs that are scheduled to report for duty on that shift. From the attendance list, the supervisor assigns both lead mechanics and AMTs to various maintenance tasks. Generally, the lead mechanics are specifically assigned to one or more particular aircraft with a complement of mechanics which the supervisor envisions as necessary to complete the maintenance.

Process various logs

Each supervisor periodically initiates, reviews, updates and completes several logs that are procedurally required by corporate policies. The logs not only record events that occur during the shift, but also assist the supervisor with the performance of various tasks. The logs address all events that occur during the shift (e.g., OJIs, success or failure to meet schedules, manpower and work load allocations, and interdepartmental communications). The log entries may also include items that pertain to parts, support shop availability, interdepartmental communication (engineering, management, factory representative, etc.), and safety/HAZMAT issues. In addition to maintaining the logs, the supervisor periodically completes reports concerning overtime usage and aircraft status.

Participate in shift meetings

The supervisor is required to attend several meetings during the work shift. During these meetings, the supervisor addresses aircraft and equipment status as well as production and workload problems. The meetings also provide a forum for the supervisor to interact and coordinate with other skills.

Assume shift/hangar manager tasks as required

At times, the supervisor may be required to acquire the overall control of the entire facility. This additional responsibility will entail the overseeing of all maintenance activities within the entire complex. The designated supervisor will have temporary control over all skill and aircraft maintenance foreman.

Assign tasks to lead mechanics

A lead mechanic may be designated as a substitute for and by the on-duty supervisor. The assignment provides two specific benefits for the supervisor -- work load relief and supervisory training for the lead mechanic. The work assigned to the lead mechanic may encompass duties that require supervisory authority and/or decision making, and as such these credentials are handed down to the lead mechanic to expedite and to learn.

Receive and perform tasks from management

The supervisor, in addition to his normal duties, periodically receives from upper management various additional tasks and assignments. As the supervisor's task encompass so much of the overall activities, technical knowledge, and personnel-related interaction within the maintenance complex he is looked upon as a vital resource for upper management's needs.

Approve payroll

At most larger maintenance facilities, payroll is performed through electronic entries. These systems, however, still require supervisory sign off approval. This function becomes a periodic task that is not delegated to a lead mechanic, and, therefore, its review and approval is exclusively handled by the supervisor.

Monitor compliance with standards and procedures

Since company and federal policies are critical to the continuation of federal licensing, the maintenance of overall compliance is generally the responsibility of the attending supervisor. The enforcement and assurance of these mandates are constantly monitored by the effective supervisor.

Perform miscellaneous office tasks

The nature of the overall administrative tasks provide several miscellaneous tasks that occupy the supervisor's time in answering the telephone, e-mail, and inquiries, copying forms, and other general office housekeeping activities.

Personnel

The Foreman has six major tasks which involve personnel: 1) perform disciplinary actions (or rewards as circumstances dictate), 2) counsel lead mechanics and AMTs, 3) assignment of personnel (AMTs and LMs) to aircraft and monitor their work, 4) provide guidance, assistance, and training to lead mechanics, 5) conduct periodic performance reviews, and 6) meet with labor representatives as needed (Section 3.9.2). The following describes the tasks in greater detail.

Perform disciplinary actions (or rewards as circumstances dictate)

The foreman is also tasked with the responsibility of disciplining individuals. Although the AMT culture is endowed with a high degree of accountability and responsibility, there are times when intervention is required to assure adherence to policies and procedures. The foreman, depending upon the work environment (no labor agreement), is required to participate in corrective action relative to the AMT's or lead mechanic's conduct. Generally, when an event occurs, the foreman initially "speaks" to the offender outlining the error or offense that was identified. Usually this is sufficient, and no further action is required. It should be noted that the lead mechanic, in the case of an offending AMT, usually completes this level of correction. If a failure to achieve correction is experienced, then the foreman is brought in. In the aforementioned disciplinary action, "speaking" may result in a letter outlining the event and any discussions that occurred. This document is signed by all parties involved (foreman, lead mechanic, and AMT), and is placed in the employee's personnel file for a predetermined period of time. If at the conclusion of the designated period the issue has been resolved, the letter is removed and no further action is taken. The issue becomes closed without record. However, if there is no resolution, the issue is reopened, re-discussed, and reviewed. If no possible resolution is apparent, a permanent letter is placed in the employee's file, denoting the event, additional review, and conversion of the temporary letter to permanency. This sequence may be followed as often as the foreman decides. Continuation of this procedure may result in attaining a "short" suspension of work (without compensation) for the offender or longer and subsequent suspensions, all documented, until termination.

Facilities operating under a negotiated labor contract have specific and detailed procedures pertaining to discipline. Generally speaking, the first level of nonunion supervision upon noting an "event" discusses the issue with a designated representative of the labor organization. This may result with the representative discussing the issue with the offender and attempting resolution (with no further action), or with the offender, first level nonunion supervision, and the labor representative discussing the issue collectively to achieve a collective and endorsed resolution. Failing success in attaining a satisfactory resolution, a grievance procedure may be instituted by the claimant against the offense. The grievance may be resolved by mutual agreement between the parties involved, or, if necessary, by arbitration. Failure of the offender to comply with a arbitrated resolution could result in suspension or termination proceedings.

Counsel lead mechanics and AMTs

Although not directly observed, interviews with the foremen revealed that counseling their lead mechanics and AMTs on personal matters was a task that they routinely performed. Individuals occasionally have personal problems (e.g., financial, marital, family, etc.) that may affect their work. It is important that the supervisors are aware of these problems so that they can take any actions necessary. Sometimes, an individual will approach the foreman with the problem, while at other times the foreman will approach the individual after observing an unusual or uncharacteristic work performance.

Conduct crew briefings

Periodically it may become necessary for the supervisor to address specific issues concerning corporate, departmental, or federal policies and/or procedures. In order to effectively disseminate the information, the supervisor uses a crew briefing meeting. The briefings may also concern local policy issues that the supervisor feels is important. The briefings showed a positive two-way flow of information between all parties.

Provide guidance, assistance and training to lead mechanics

The AMT culture has historically provided a progressive training system for supervisory personnel through the application of an apprentice/mentor relationship. As AMTs are guided and encouraged to prepare for advancement to lead mechanic (predominately in organizations without labor agreements), lead mechanics are identified for potential advancement to foreman. Once identified, the foreman incorporates a training element into the lead mechanic's assignments. This training may involve decision making relative to personnel assignments, work planning and assessments, and interdepartmental activities that parallel the foreman's normal duties.

Conduct periodic performance reviews

Performance evaluation is a task that is performed at regular intervals as specified by the organization. Because evaluation forms are used, this task could have been included in the administrative category. However, the majority of the activities associated with this task involves interactions between the foreman and the lead mechanic/AMT. Actual evaluation procedures vary depending on the circumstances. Therefore, a more detailed breakdown of evaluation activities was not made.

Meet with labor representatives as needed

The maintenance foremen whose organization is operating under an organized labor contract are required to interface with labor representatives concerning the application of various work rules and personnel issues. Many of the issues are generally resolved with mutual and amicable discussion. This subtask does require contractual knowledge, understanding, and interpretation along with (in many cases) authoritative diplomacy. Although, this additional knowledge and comprehensive understanding would not be necessary in noncontractual facilities, interpersonal relationship skills remain an important and fundamental requirement throughout all of the supervisor's tasks.

Operations

Within the category of operations, the foreman has the major tasks of: 1) receiving aircraft, 2) assigning aircraft and personnel to the lead mechanic, 3) receiving aircraft status from the lead mechanics, 4) monitoring work performance, 5) updating crew and aircraft assignments throughout the shift, and 6) coordinating out-of-town trips (Section 3.9.3). Interwoven throughout the major operations tasks is the coordination with the shift manager/operations manager, other skill foreman and other departments within the organization. This coordination allows for the timely flow of vital information both vertically and horizontally throughout the organization. All information concerning the work status, maintenance problems, and delivery times go through the foreman or his appointed substitute. The following describes the six major tasks in more detail.

Receiving aircraft

The supervisor, upon reviewing the planned work for both inbound aircraft and those scheduled for departure, must remain attentive to the facility's capabilities and committed production schedules. The anticipated arrival of new work, scheduled departure of completed work, and delays of planned work necessitate forward (in hours and days) planning. This is considered an operational task that bears heavily upon the success and effectiveness of the supervisor's duty. The ability to rethink and replan the activities and assignments when anticipated events change provides the overall operation effectiveness.

Assigning aircraft and personnel to the lead mechanic

Through coordination with the shift manager/operations manager, the foreman receives and reviews information on aircraft currently in the maintenance facility as well as aircraft scheduled to arrive during the shift. By combining this information with personnel availability from the crew sheet, the foreman assigns the necessary number of AMTs with their lead mechanics to the various aircraft. At this point, the foreman may also assign specific tasks primarily to the lead mechanics as well as the AMTs. These specific tasks include such things as the transportation of mechanics and related personnel to aircraft outside of the immediate maintenance facility (i.e., to another airport to conduct scheduled, unscheduled or emergency maintenance), the transportation and movement of aircraft to and within the maintenance facility, and other tasks as required by the foreman. These additional tasks can include nontechnical work such as assisting the foreman in performing miscellaneous office procedures.

Throughout the shift, the foreman monitors the AMTs and lead mechanics under his/her control. Typically this involves a walk through inspection of the work being performed. The foreman/manager not only observes the quality of work being performed, but also notes items such as unsafe acts, use of nonstandard procedures, mishandling of equipment, etc. Though usually done at the beginning of the shift, the task of monitoring the work of the lead mechanics and AMTs is performed throughout the shift at the discretion of the foreman/manager. The task of monitoring has no set procedure. Rather, it is based on the knowledge and experience of the supervisor, and varies from person to person. As a result, the monitoring task is not broken down into subtasks or activities.

Receiving aircraft status from the lead mechanics

The observed supervisors had established and tasked personnel within the operation to maintain a constant feedback of production events and aircraft status. Although many decisions were handled by the lead mechanics without the supervisor's advice, the decisions and results were presented to the supervisor in a timely manner. The importance of this feedback defined two critical factors for the supervisor. First, it allowed for effective planning or replanning for the supervisor. Second, it demonstrated the lead mechanic's training, capabilities, and limitations to the supervisor for later evaluation.

Monitoring work performance

At both facilities the supervisor would periodically journey throughout the work areas. This was done for several reasons: 1) to review and update his reports as to the progress of critical operations, 2) to compare the planned schedule against the actual, allowing for possible reevaluation, and 3) to provide his personal presence at the work sight. It also allowed the supervisor to learn and understand the current complexities and technical aspects of new work and work environments which would provide improvement and accuracy in his future planning

Updating crew and aircraft assignments throughout the shift

Due to the dynamic nature of an aircraft maintenance environment, the supervisor relies heavily upon information flow and feedback from the work areas to control scheduling. Priorities and demands oftentimes change during the work period, and supervisors demonstrated both the flexibility of their personnel and capabilities of their organizations to change assignments, resources and focus as the situation demanded.

Coordinate out of town trips

Occasionally an aircraft may develop a mechanical problem that requires landing at an airport that may not be served by that operator. Or, the aircraft may be located at an airport that, although served by the operator, may not have the maintenance facilities nor capabilities required to return it to service. Both of the analyzed facilities were capable and qualified to support field maintenance. The request for field support is forwarded to the supervisor along with information pertaining to the type of aircraft, mechanical problem, location, and aircraft status. The supervisor responds by taking the necessary action to gather the required staffing, tools and equipment, and replacement parts. The scheduled and relative times, necessary arrangements, clearances and paperwork are all executed by the supervisor to effect a prompt resolution. In addition, the activities of several interrelated internal departments and external agencies (DOT/FAA/NTSB) must be coordinated by the supervisor to insure a timely and successful off-site maintenance activity.

3.3.2 Lead Mechanic

The aircraft maintenance lead mechanic is generally selected or promoted from the ranks of the aircraft maintenance technicians. As with the foreman, the technical knowledge and skills required to perform the supervisory functions were derived from experiences as a mechanic. The major goal of the lead mechanic is the timely delivery of the aircraft. The completion of this goal is dependent on the effective use of his/her personnel and acquired technical skills. The following describes the major task categories, tasks and subtasks performed by the lead mechanic.

Administrative

Administrative tasks for the lead mechanic were defined as procedural tasks that do not directly affect personnel or the maintenance of the aircraft. Five major tasks were identified: 1) checking the AMAs and HMAs upon arrival at work, 2) checking in with the foreman upon arrival at work, 3) updating the time and attendance sheets for AMTs, 4) scheduling physical exams for the AMTs, and 5) assuming the foreman's tasks when the foreman is not present (Section 3.9.4). The following is a brief description of each of these tasks.

Checking the AMAs and HMAs upon arrival at work

Aircraft Maintenance Alerts (AMAs) and Hangar Maintenance Alerts (HMAs) are publications that provide information that is critical to the maintenance of the aircraft or hangar operations. The AMAs and HMAs are posted for all personnel to read and review. One of the lead mechanic's tasks involves reading the AMAs/HMAs and signing them to attest that they have been read. Although this task may be done at any time during the shift, lead mechanics typically read and sign the AMAs and HMAs at the beginning of their shift.

Checking in with the foreman upon arrival at work

Checking in with the foreman at the beginning of the shift was identified as a separate nonformalized task under the administrative category. Although the lead mechanic was usually assigned an aircraft and personnel during this task (and thus potentially could fall under either the personnel or operational categories), it was considered administrative since it did not necessarily involve people or aircraft. The check in procedure confirms for the foreman/manager that the lead mechanic was present and available for assignment.

Updating the time and attendance sheets for AMTs

At one repair station, the lead mechanic was tasked with updating the time and attendance sheets of the AMTs. This task involves collecting individual time and attendance sheets, and compiling them onto a master sheet to be submitted to the payroll office. Lead mechanics may elect to perform this task in a single session at the end of a pay period, or may choose to update the master sheet throughout the pay period as time permits.

Scheduling physical exams for the AMTs

In order to move or operate any and all powered equipment (e.g., tugs, cranes, aircraft, etc.), each AMT in demonstrating their proficiency, must also receive and pass a medical examination. For an aircraft taxi license, there are two exams that are required: (1) a yearly physical examine which is conducted off-site in a physician's office, and (2) a semiannual audio and visual test which is typically done on site at the nurse's station. It is the task of the lead mechanic to arrange for the AMTs to have these physical examinations. The task is a fairly simple one consisting of evaluating current and future manpower needs (to determine if the aircraft ready time would slip due to temporary loss of an AMT), and calling the appropriate office to schedule an appointment.

Assuming the foreman's tasks when the foreman is not present

The most demanding administrative task required of a lead mechanic is to assume the duties of the foreman. There are occasions when the foreman is temporarily absent (illness, training, or other assigned duties). In these cases, the foreman will assigned his duties to an available lead mechanic. These appointed duties are described in the discussion of the foreman's tasks.

Personnel

In the personnel related task category, seven major tasks were identified (Section 3.9.5): 1) provide counseling, 2) provide discipline and rewards, 3) provide training, 4) conduct qualification checks, 5) assign work to AMTs, 6) evaluate performance, and 7) hold crew meetings. The following is a brief description of each of these tasks.

Provide counseling

Although not performed on a consistent basis, providing personal counseling is an important task of the lead mechanic. This task is similar to that performed by the foreman, but since the AMTs are closer to the lead mechanic, the AMTs usually approach the lead mechanic first. The lead mechanic tends to be limited in the help that they can provide, but quite often, just having someone in authority to talk with is helpful to the person with a personal problem. Work-related counseling is another counseling task performed by the lead mechanic, and is sometimes referred to as coaching. If an AMT's work quality slips or if an AMT's work habits deteriorate, it becomes the task of the lead mechanic to counsel the AMT on how to improve performance. Lead mechanics sometimes consider counseling as a precursor to disciplinary action.

Provide discipline and rewards

When a mechanic fails to comply with work standards, or ignores the counseling efforts of the lead mechanic to help improve performance, it becomes necessary for the lead mechanic to discipline the AMT. Most lead mechanics take pride in the fact that they can handle problems without resorting to disciplinary action; however, when forced to do so, the lead mechanic follows the procedures established by the organization. Usually, the first level of an official disciplinary action (beyond work counseling) is the "verbal warning." Not only does the lead mechanic tell the offending AMT that he is being given a "verbal warning," but also the lead mechanic must record the date, time and purpose of the warning. If the AMT still does not comply with established standards, the lead mechanic will initiate a "written warning." The "written warning" is the second level of disciplinary action available to the lead mechanic. The lead mechanic has no disciplinary action available past "written warning." If the offending AMT still refuses to comply with the organization's rules and regulation, the lead mechanic will turn the problem over to the foreman to handle. Unlike discipline, the task of rewarding an AMT who performs above and beyond expectations tends to be unofficial. Because the lead mechanic has authority over job assignments, the lead mechanic will typically assign lighter duties to those individuals who deserve a reward.

Provide training

Providing training is a major task under the personnel-related tasks category. Providing training consists of determining training needs of the AMT, giving on-the-job training (OJT), and providing instructions on the use of mechanized equipment. The performance of the first task (determining training needs) will vary depending on the current skill level of the AMT and presence of new technology. A lead mechanic may determine that an individual needs a refresher course in a particular maintenance operation, or, if there has been a technological change or improvement in the aircraft, schedule the appropriate training.

Conduct qualification checks

As previously mentioned, a mechanic must also be qualified to use any powered equipment. The most difficult qualification to obtain is the taxi check. The process of qualifying to taxi an aircraft starts with riding in the copilot seat to learn the procedures. The mechanic will eventually move to the pilot seat and taxi under the supervision of a qualified individual. Once the mechanic shows that he is capable of taxiing the aircraft, the lead mechanic will conduct a qualification check. The qualification check is considered a separate task.

Assign work to AMTs

Another task performed by the lead mechanic is the assignment of work to individual mechanics. The lead mechanic receives one or more aircraft and a list of the personnel available to him. The lead mechanic must then assign the mechanics to the various tasks that need to be completed. The assignment task involves technical knowledge of the work to be accomplished, an understanding of the abilities of the mechanics on the crew, delivery time constraints, previous work assignments, reward and discipline concerns, and any special directives from the foreman or upper management.

Evaluate performance

Once the mechanics have been assigned to their jobs, the lead mechanic has the task of monitoring the work being performed. Although similar, the monitoring of work conducted under the category of personnel-related tasks is different than monitoring tasks performed under the category of operational related tasks. Monitoring of work under personnel-related tasks is associated with quality as opposed to production levels. Repairs made by an AMT may be adequate for airworthiness, yet be of poor quality. Through monitoring, the lead mechanic ensures high quality workmanship. There is no set structure to the monitoring task, rather the lead mechanic observes the AMTs at work, then uses his/her technical knowledge and expertise to recognize: 1) the level of work quality, 2) whether the equipment is being used properly, 3) the physical safety of both the aircraft and the personnel, and 4) if proper hazardous material handling procedures are being followed.

Hold crew meetings

Holding crew meetings is another task of the lead mechanic. These meetings are held at the discretion of the lead mechanic, but usually occur when there is no adverse impact on aircraft delivery time. During these meetings, the lead mechanic may discuss any number of concerns to include: future work, ways to improve quality, and technical or interpersonal relationship problems.

Operations

Operational tasks consume a majority of the lead mechanic's time and effort. This is not unexpected since the maintenance lead mechanic has final responsibility for the airworthiness of the aircraft. The category of operations-related tasks has seven major tasks (Section 3.9.6): 1) receiving aircraft, 2) conducting preflight checks, 3) releasing aircraft, 4) monitoring work production, 5) coordinating out-of-town maintenance trips, 6) conducting administrative work directly related to the aircraft, and 7) obtaining parts for the maintenance of the aircraft. The following is a briefly description of each of the major tasks.

Receiving aircraft

The lead mechanic may receive an aircraft in two ways: by a turnover from a previous shift or as an arrival of an aircraft during the shift. Likewise, the lead mechanic may release an aircraft through a turnover to a subsequent shift or by finishing all maintenance and releasing the aircraft back into service. Turnovers occur at the beginning and end of each shift, and are usually conducted in the following manner. The lead mechanics meet at the aircraft being discussed so that specific problems may be pointed out, the releasing lead will review the work that has been accomplished, current status, and any problems that have occurred. The receiving lead will ask questions for clarification, and then check paper work to ensure that the work that has been accomplished has been signed off and that all the remaining paperwork is in order. When receiving an aircraft during a shift, the lead mechanic has the subtasks of securing the aircraft from the line, preparing the hangar area to receive the aircraft, parking the aircraft in the proper location and preparing the paperwork package for the arriving aircraft. If an aircraft is to be released during the shift, the lead mechanic must complete all the necessary paperwork for release, make a final inspection of the aircraft, sign and turn in the airworthiness release, and finally, notify the organization of the aircraft's availability.

Conducting preflight checks

There are occasions when a preflight check must be conducted prior to the release of the aircraft. This task involves coordinating with other skills, checking out a preflight handbook, moving the aircraft to the preflight test site, conducting the tests, and releasing the aircraft for service.

Releasing aircraft

The tasks involved with releasing an aircraft are closely associated with receiving an aircraft.

Monitoring work production

As previously mentioned, the lead mechanic monitors the work of the AMTs both for production as well as for quality. Within the tasks of monitoring work under the operations related category, the lead mechanic moves between work sites to evaluate production, determines aircraft status to relate to the foreman, and facilitates the work being done by the AMTs. Facilitation of work includes various subtasks such as ordering parts, lending a helping hand and providing technical expertise.

Coordinate out-of-town maintenance trips

A field maintenance event, which normally is tasked to the supervisor, may be delegated to a lead mechanic. The delegation may occur due to workload or to provide a training element for the lead mechanic. In either case, the assigned lead mechanic will coordinate and establish the entire agenda. Additionally, the designated lead mechanic may in fact become the supervisor in the field to lead and conduct the work as part of his/her supervisory training.

Conducting administrative work directly related to the aircraft

Throughout the process of conducting maintenance on the aircraft, the lead mechanic is tasked with administrative work. Since these administrative tasks are directly related to the maintenance of the aircraft, they are grouped under the operations related task category. The administrative paperwork is broken down into the subtasks of: initiating and updating the shift log, updating the aircraft log (in most cases the AMT updates the aircraft log; however, the lead mechanic is responsible for the completed log) and initiating and updating compliance (check) sheets. As a final administrative task, the lead mechanic must routinely report the status of the aircraft to the shift foreman/manager.

Obtaining parts for the maintenance of the aircraft

Ordering parts is a major task for the lead mechanic. It is also fairly complicated, involving many subtasks and activities. It is not within the scope of this report to detail all the decisions and processes involved with ordering parts for the aircraft. There are, however, three major subtasks involved with ordering parts. First, the part number must be determined. There are a number of ways this may be accomplished if the part number is not readily available. Second, an order for the part must be placed with the appropriate subsystem. Finally, once a part is secured, it must be delivered to the appropriate work site.

3.4 TASK ANALYSIS

With the understanding that the supervisor has responsibilities for organization, effective communication, and quality control as well as for providing technical expertise, each of the major tasks in this study was analyzed with respect to a select set of leadership skills. Leadership has been studied and analyzed in many different ways, but the research can be classified according to the primary focus: leadership traits, leadership skills, behavior, power and influence, or situation factors.[3] This study focuses on the skills related to effective leadership. The use of the word "skill" implies an ability which can be developed through training and practice. It is not enough that a person has the appropriate traits of a leader, but that person must also have good leadership skills to be effective.

In an early taxonomy of leadership skills, Katz[4] identified three basic developmental leadership skills:

1) Technical skills - an understanding of and proficiency in methods, processes, procedures and/or techniques associated with a specific kind of activity.

2) Human skills - an ability to work effectively as a group member building cooperative efforts towards a common goal.

3) Conceptual skills - the ability to see and understand the organization as a whole; to include how the various functions depend on one another, and thus how to coordinate and integrate all the activities towards a common goal.

Mann[5] also identified three similar supervisory skills: technical skills, human relation skills and administrative skills. In addition, Mann noted that the mix of these skills varied depending on the supervisory level within the organization. First level supervisors tend to have a larger amount of technical skills with less human relation and conceptual skills. Higher level supervisors, on the other hand, have more human relation and conceptual skills as opposed to technical skills.

The skills/competencies identified by Katz[4] and Mann[5] are reflected in the three main task categories identified in the aircraft maintenance environment: administrative-related tasks, personnel-related tasks and operations-related tasks. In order to analyze the tasks within each category, however, specific skills for effective leadership needed to be identified. Yukl and Van Fleet[3] suggest that specific skills for effective leadership should include: analytical abilities, persuasiveness, speaking ability, memory for detail, empathy and tact. In the American Assembly of Collegiate Schools of Business (AACSB) Outcome Measurement Project Report,[6] nine skills and personal characteristics (SAPC) were identified and defined. The nine SAPCs in the research are:

1) Analytical
2) Computer
3) Decision
4) Initiative
5) Leadership/interpersonal
6) Oral communication
7) Planning/organizing
8) Risk taking
9) Written communication

Mullin, Shaffer and Grelle[7] summarized a number of taxonomies of the basic management skills essential to good leadership. These taxonomies are displayed in Table 3.1 where it can be noted that there are many similarities between leadership skills taxonomies.

Table 3.1 Taxonomies of Basic Management Skills[7]

1959	1988	1988 Development	1984	1989 Big Eight
Gordon & Howell	Porter & McKibbin	Dimensions Inc.	Cameron & Whetten	Accounting Firms
PROBLEM-SOLVING	ANALYTICAL	ANALYSIS	CREATIVE PROBLEM-SOLVING	INTELLECTUAL
				Problem-solving
DECISION-MAKING	DECISION MAKING	JUDGEMENT		Creative
Analysis			GROUP DECISION MAKING	Unstructured
Judgment	RISK TAKING			Problem anticipation
			SELF AWARENESS	Inductive thought
			Ethical issues	Judgment
ORGANIZATIONAL	PLANNING/ ORGANIZING	PLANNING & ORGANIZING	IMPROVING EMPLOYEE PERFORMANCE	Value-based reasoning
Information flow				Organization of work to meet priorities
Division of labor		DELEGATION CONTROL	DELEGATION & JOINT DECISION MAKING	
Plan, delegate, coordinate				
INTERPERSONAL RELATIONSHIPS	LEADERSHIP/ Interpersonal	LEADERSHIP	MANAGING CONFLICT	INTERPERSONAL
		Individual		Influence
		Group		Delegation
Strong personal motivation (attitude that contributes indirectly to skills)	Initiative (attitude that contributes indirectly to skills)	Disposition to lead (attitude that contributes indirectly to skills)	MANAGING PERSONAL STRESS	Motivation
			GAINING POWER & INFLUENCE	Conflict resolution

COMMUNICATION	COMMUNICATION	COMMUNICATION	ESTABLISHING SUPPORTIVE COMMUNICATION	COMMUNICATION
Oral & nonverbal	Oral	Oral:		Presentation
Verbal, numerical	Written	Communication		formal/informal
Idea formulation		Presentation		oral/written
Generating/ transmitting		Written		Listening
receiving/interpreting	Computer Skills			obtain & organize
non-quantitative &				information
quantitative				
information & data				

Based on the aforementioned research, seven leadership skills were identified that impacted the effective performance of the supervisor. Table 3.2 provides a list of the skills along with a definition and example of the use of the skill within the aircraft maintenance environment. An analytical methodology similar to that used to analyze maintenance technicians in inspection8 was used in this study.

Table 3.2 Definition With Example Of Leadership Skill

Leadership Skill	Definition	Example
Technical skills	Those skills necessary to understand and perform maintenance on an aircraft	Conducting and directing corrective maintenance action and activities on an aircraft or related components
Procedural/ Administrative skills	Those skills required to correctly perform the various procedures and administrative tasks required by federal or organizational regulations	Releasing or signing the airworthiness or serviceability of an aircraft or related component after maintenance work has been completed
Communication skills	Skills necessary to effectively send a message (verbal or nonverbal) to a receiver (or receivers) in order to affect the receiver's behavior	Assigning personnel to aircraft or component maintenance tasks and receiving information pertaining to productivity and obligations
Decision-making skills	Skills required to reach the best solution to a problem when the correct answer is unknown	Determining the effective course of maintenance, corrective activity and or personnel assignment to complete aircraft or component maintenance and repair work
Coordination skills	Skills necessary to interact in effective agreement with other skills, departments or organization in order to efficiently complete a task	Effective use of all resources and associated maintenance organizations for completion of individual work assignments or aircraft delivery
Interpersonal skills	Those skills necessary to interact effectively with others so that the consequences of a person's behavior matches his intentions	Dealing with aggressive personnel in complex personal, technical and authoritative manner
Situation awareness skills	Skills necessary to perceive and understand the state of the aircraft system (subsystem) in order to minimize errors, interpret information and to coordinate crew members	Cognizant of maintenance activities and assigned work by dedicated and ancillary work groups that may impact aircraft maintenance assignments including personnel safety

Sections 3.9.7 and 3.9.8 show the task analysis document used for the two supervisory levels (lead mechanic and foreman/manager). As previously described for each supervisory level there are three main categories: administrative related tasks, personnel related tasks and operations related tasks. Each of the major tasks within the categories are listed, and the use of a particular skill employed in that task is indicated. Subtasks as well as observations are also provided in the documents.

3.5 INTERVENTION STRATEGIES

An evaluation of the task analysis was done by summing the occurrence of each leadership skill within the three task categories for both the lead mechanic and the foreman. For comparison purposes, the numbers were normalized to a scale of 0 to 1. The results (Table 3.3) reveal several possible intervention strategies to assist the aircraft maintenance supervisors in the performance of their job. The following sections will describe potential job aids for the supervisor along with rationale for nondevelopment or development.

Table 3.3 Occurrence of Leadership Skills by Task Category

	Task	Skill						
Supervisor	Category	T	P	Com	D	Coor	I	SA
Foreman	Administration	0.54	0.73	0.54	0.91	0.45	0.36	0.36
	Personnel	0.33	0.67	1.0	1.0	-	0.83	0.17
	Operations	1	0.67	0.67	1	0.67	0.67	0.67
	Total	0.62	0.69	0.74	0.97	0.37	0.62	0.4
Lead Mechanic	Administration	0.4	0.8	0.6	0.8	0.6	0.4	0.4
	Personnel	0.71	1.0	1.0	1.0	0.43	1.0	0.43
	Operations	1.0	1.0	1.0	1.0	1.0	0.86	0.71
	Total	0.90	0.93	0.87	0.93	0.68	0.75	0.51

T: Technical skills, P: Procedural skills, Com: Communication skills, D: Decision making skills,

Coor: Coordination skills, I: Interpersonal relationship skills, SA: Situation awareness skills

3.5.1 Electronic Job Aid

The use of procedural/administrative skills scored high for the lead mechanic (0.93) and moderately high for the foreman (0.69). The lower score for the foreman may have been due to the fact that in both companies, the foreman currently uses a computer to aid him in his work, thus minimizing administrative duties. Many of the administrative tasks observed for the lead mechanic consisted of documentation of current events that occur during the duty period. Events, whether positive or negative to the success of productivity, are listed on the lead mechanic's running log. Upon completion of the assignment (shift or aircraft) this information is filed for review or investigation if after-the-fact aircraft incidents warrant. The possibility of an electronic job aid for event data would simplify the administrative tasks by providing a real time medium with an enhanced database on site. The availability of pertinent reference data, historical references, task assignments, technical instructions, etc. would help minimize the administrative duties required of the lead mechanic. In addition, entries into an electronic log could provide a flexible analytical database that could be used to identify selected and repetitive problems/events occurring during the course of the tasks. This database could then be used to identify areas of concern that may need improvement or restructuring.

This job aid was eliminated from possible development for two reasons. First, a proposal of such an electronic job aid was presented to the lead mechanics of one repair station. The response received was one of appreciation that such a devise could assist them to some degree. However, it was felt that such a devise would cause a unwanted encumbrance when weighed against the potential benefits a prototype may provide. Additionally, the physical presence of this device would have required it to be exposed to various hostile environments where potential physical damage, and/or accidental abuse/misuse could be incurred. The overall summation from the lead mechanics was that the electronic advantages were outweighed by physical disadvantages. Secondly, a similar (but without log entries capabilities) prototype job aid was currently under development for application within a certified component repair facility (Chapter 1). The conceptual attributes, though not identical, were sufficiently similar to the envisioned hangar prototype that this effort would be a duplication of effort.

3.5.2 Training Program for Technical Knowledge and Expertise

Technical skills are an important aspect of a lead mechanic's functions. This is reflected in the high technical skills score shown in Table 3.3. In order to understand what manpower and physical resources are required for a maintenance task, the lead mechanic must first have the knowledge and understanding of the technical aspect of the job. Anecdotal evidence revealed that when a lead mechanic does not have an understanding of maintenance tasks, he puts himself at risk with the AMTs. The AMTs tend to lose respect of a supervisor with limited technical expertise as they generally rely upon the lead mechanic's technical background as an educational and labor reducing asset. The technical aspects of the AMT culture fall into three identifiable categories: 1) general/basic aircraft maintenance knowledge (this is generally provided by certified A&P Technical Schools), 2) aircraft and aircraft system specific knowledge (this knowledge is generally provided by in-house or in-manufacturer's training facilities), and 3) acquired experience (this is usually obtained by familiarity and/or longevity). It is for this reason that lead mechanics are typically promoted up from the ranks of AMTs after demonstrating their technical proficiency and potential leadership capabilities.

Foreman, on the other hand, do not have to apply their strong technical skills in order to perform their functions. As previously mentioned, the mix of leadership skills can vary depending on the level of supervision, and the higher the supervisory level the fewer technical skills are necessary. Table 3.3 gives a total score of 0.62 for the use of technical skills by the foreman.

Obtaining effective technical knowledge and expertise is typically accomplished through classroom instruction and on-the-job training (OJT). The industry has historically provided AMTs technical training via in-house or in-manufacturer's factory schools when either new equipment is placed in operation, or a significant change is implemented to the current equipment that would warrant a dedicated technical training program. Therefore, a technical training program for this requirement was not justified nor could the current training be improved upon within the scope of this program.

3.5.3 Training Program for Leadership Skills

The use of leadership skills was scored high for both levels of supervision. Table 3.3 shows the importance of communication and decision making skills for both the foreman (0.74 and 0.97 respectively) and the lead mechanic (0.87 and 0.93 respectively). In addition, throughout the data collection process, the lead mechanics and foremen mentioned the need for new supervisors to receive leadership training. Currently, the tyro lead mechanics are placed in supervisory positions, and are expected to learn leadership skills through trial and error. As a result, mistakes are often made and the training may not necessarily address the errors. Due to the strong need of leadership skills, it was decided that the development of a leadership skills training course was within the realm and objective of the Task Analysis.

Leadership skills are skills that may be developed through well designed training programs that involve both the theory of leadership as well as the practical application of leadership skills. The tyro lead mechanic should be scheduled for leadership classes to supplement administrative/procedural classes provided by the organization.

3.6 LEADERSHIP SKILLS TRAINING

The following section will discuss the curriculum of a leadership training course as envisioned for the future direction of the course.

3.6.1 Course Curriculum

The following curriculum will be provided to the supervisors by trained and qualified facilitators. It should be noted that each of the following topics contain contributing elements that overlap each other, and therefore a summation topic should be considered to integrate all the elements as factors within effective leadership.

Communications Skills

Considered as one of the most important elements of effective leadership, the presentation should include *Understanding the Dynamics of Communications.* Simulations should be included that portray the effects or consequences of *Good and Bad Communications*, *Explanations of Hearing vs. Listening*, and *Communication Etiquette.* The session should conclude with the importance and methodology of *Empathic Listening.*

Decision-Making Skills

For a dynamic and effective leader, decision-making is integral to the duties and responsibilities expected and anticipated by the organization. Curriculum materials for this training session should identify *The Importance and Influence of Effective Decisions.* The importance of identifying *How Decisions Are Made*, the *Effects of Right and Wrong Decisions*, and *Emotional vs. Logical Decisions* should also be addressed. At closing, decision-making tools can be provided by presenting *Decision Diagramming*, which allows the candidate to develop systematic methods to analyze and evaluate the decision making process.

Coordination Skills

Coordination of (and between) separate but interrelated groups and teams oftentimes becomes one of the most vital components, that involves effective leadership skills. The supervisor's ability to maintain fluidity of tasks and information between his/her organization and other groups involved in a collective effort should be part of any education event. Information on the *Reading and Understanding of People* and *Understanding Attitudes* would provide the supervisor with vital tools to formulate an effective coordinated and cooperative environment. Simulations and case studies that demonstrate *Defining Human Nature* and *Dealing with People* would provide the supervisors with insight as to the coping techniques necessary to effectively steer the necessary events into a productive direction.

Interpersonal Relationships Skills

The defining of interpersonal relationship skills provides the candidate with an understanding of how he/she needs to work with other people and to allow those individuals to work with the candidates. A subtopic of *Confrontation and Compromise* would also be a part of the session. Demonstrations and related case studies or simulations would provide insight as to the dynamics of group interaction. A successful leader should be shown how development of *Tack* and *Influence* can assist and reinforce the leadership role when situations develop that reduce the effectiveness of positive production.

Situation Awareness

Being cognizant of not only the overall scope of current events, but also that of projecting and understanding the influences and results from those activities is a vital factor that provides a successful leader with the ability to operate effectively. *Situation Awareness* would be demonstrated by simulation and/or case studies where the positive and negative results can be analyzed by the candidates. Factors that have an influential bias within a situation, such as *Stress and Stress Management*, and *Shell and Shell Management*, would be portrayed as influences on the overall awareness of both the designated leader and his/her group or team.

Combining Leadership Skills

The culmination of each identifiable topic and related subtopic would be combined into a integrated simulation where elements of each acquired skill can be exorcised and applied. The simulation, relative to the groups particular environment or culture, should portray familiar events with adequate technical facets to provide a real-time dramatization. This simulation should provide adequate times for the group to enact with the event, analyze the factors demonstrated, and identify both the positive and negative elements of the event.

3.6.2 Future Development of Leadership Training

It is envisioned that the development of the leadership training course will start with construction of a prototype course focused on one specific leadership skill. A highly interactive multimedia computer-based training program will be designed and built to supplement the leadership skills instruction provided by a qualified trainer. In addition, real life problems and situations will be obtained through interviews with a variety of experienced supervisors, and the situations will form the basis for case studies and classroom discussions. To ensure that the prototype leadership training course addresses the needs of the aviation community, the designers will work in close cooperation with aircraft repair stations. The course development will be based on the classical iterative software/instruction development methodology that follows the cycle of design, test, measure and redesign.9

3.7 ACKNOWLEDGMENTS

Special acknowledgment is given to the lead mechanics and foremen/managers of Delta Airlines and Northwest Airlines for allowing us to ask questions and observe them as they perform their many tasks.

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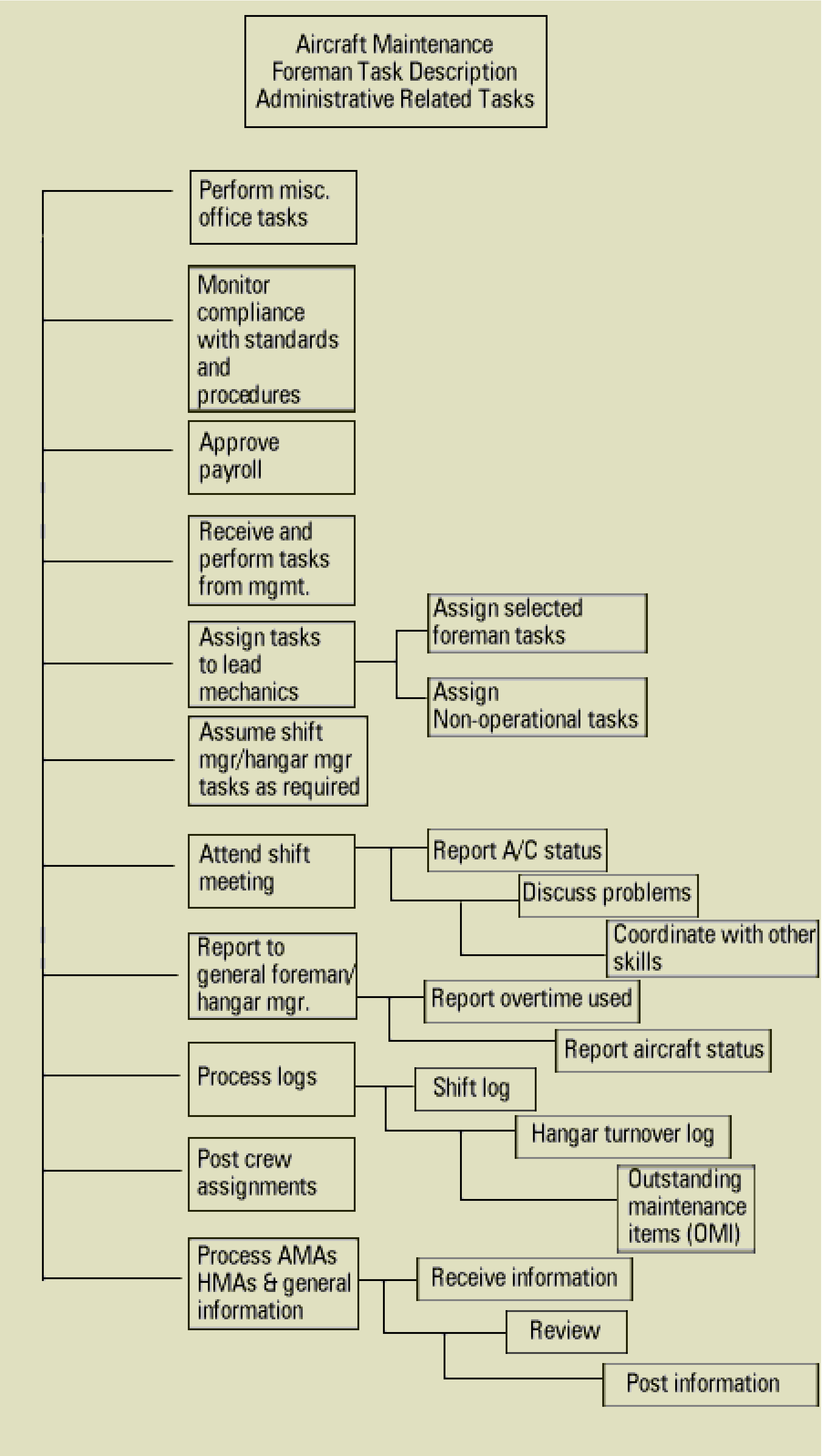
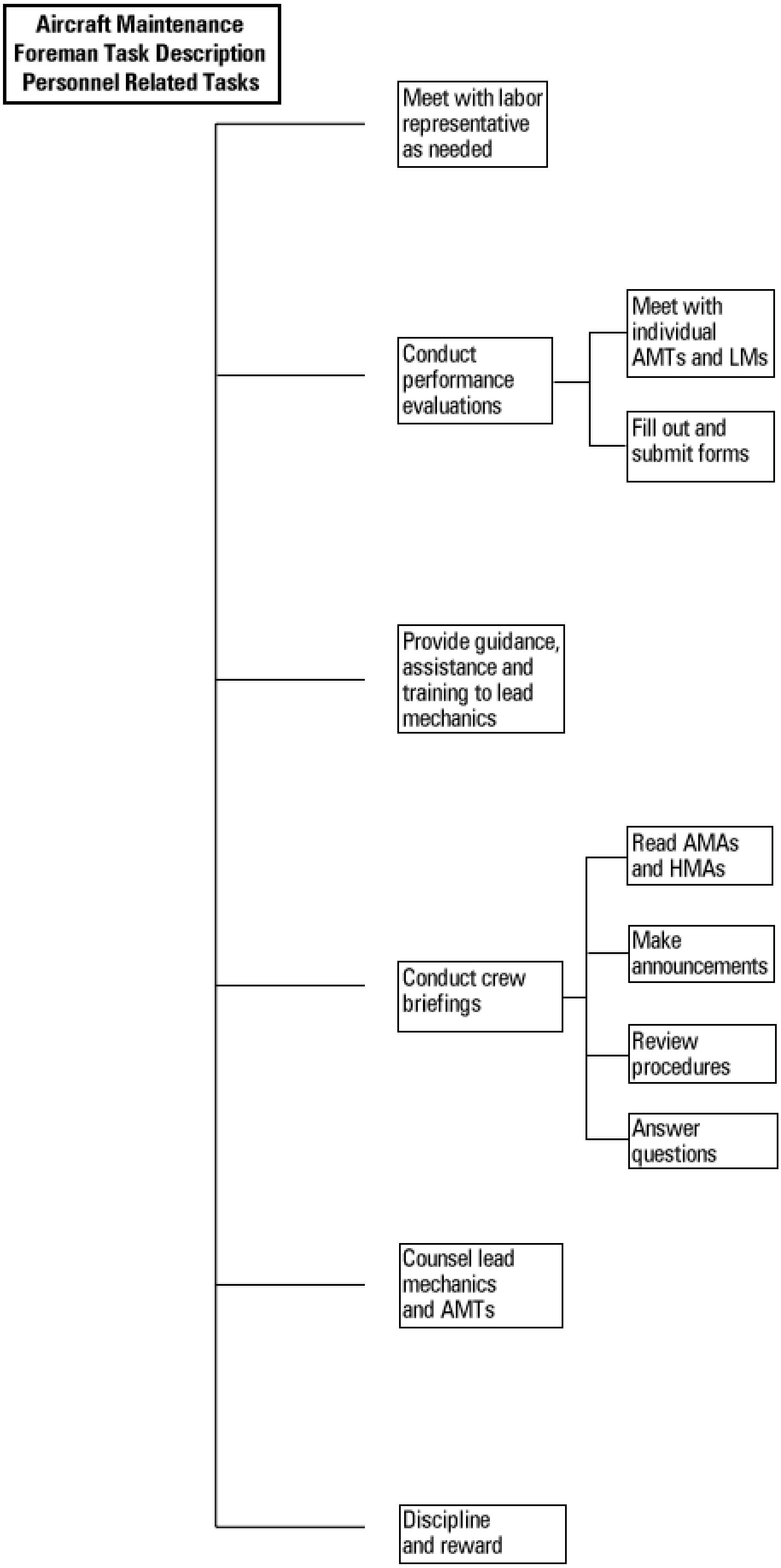
3.9 APPENDICES

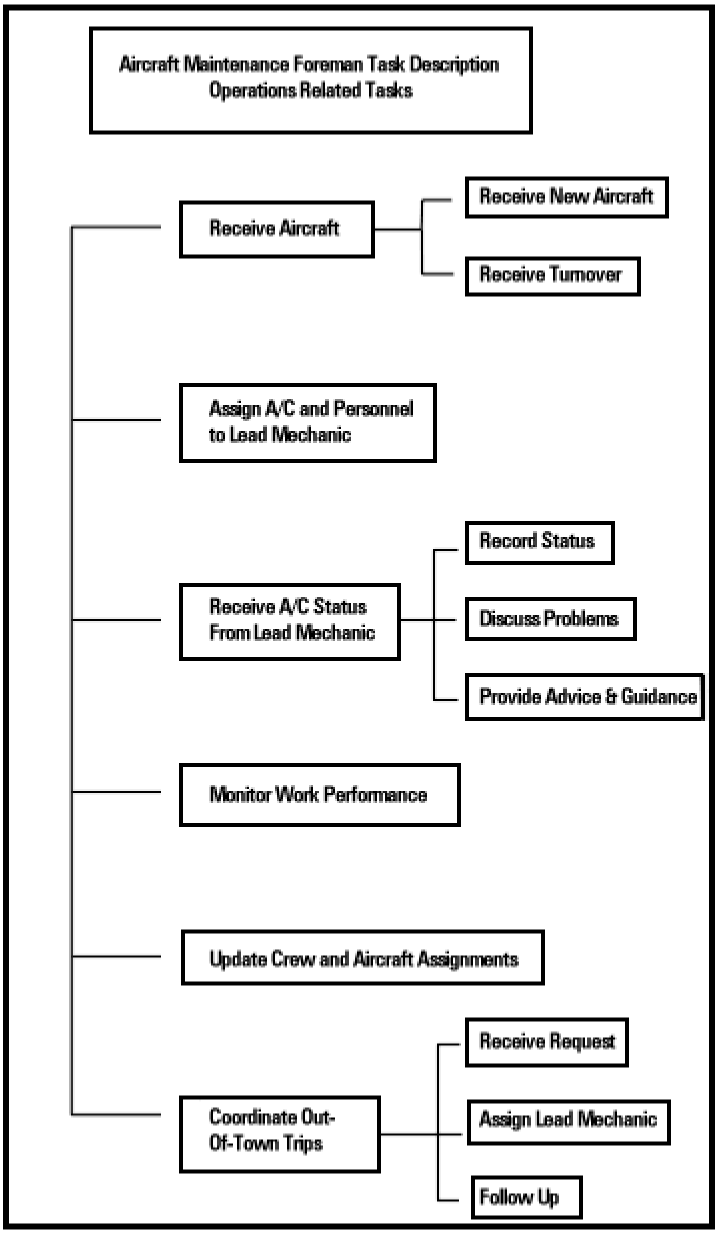
3.9.1 Appendix A Foreman - Administrative Related Tasks



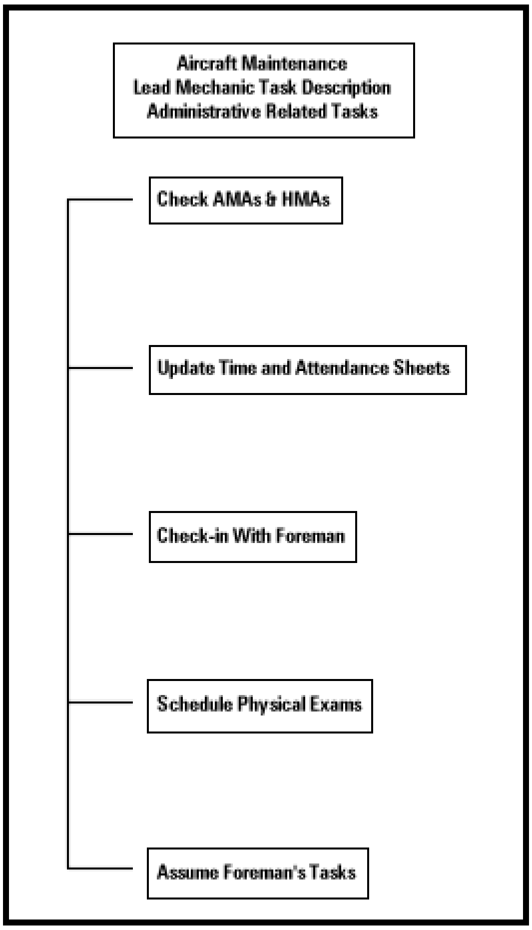
3.9.2 Appendix B Foreman - Personnel Related Tasks



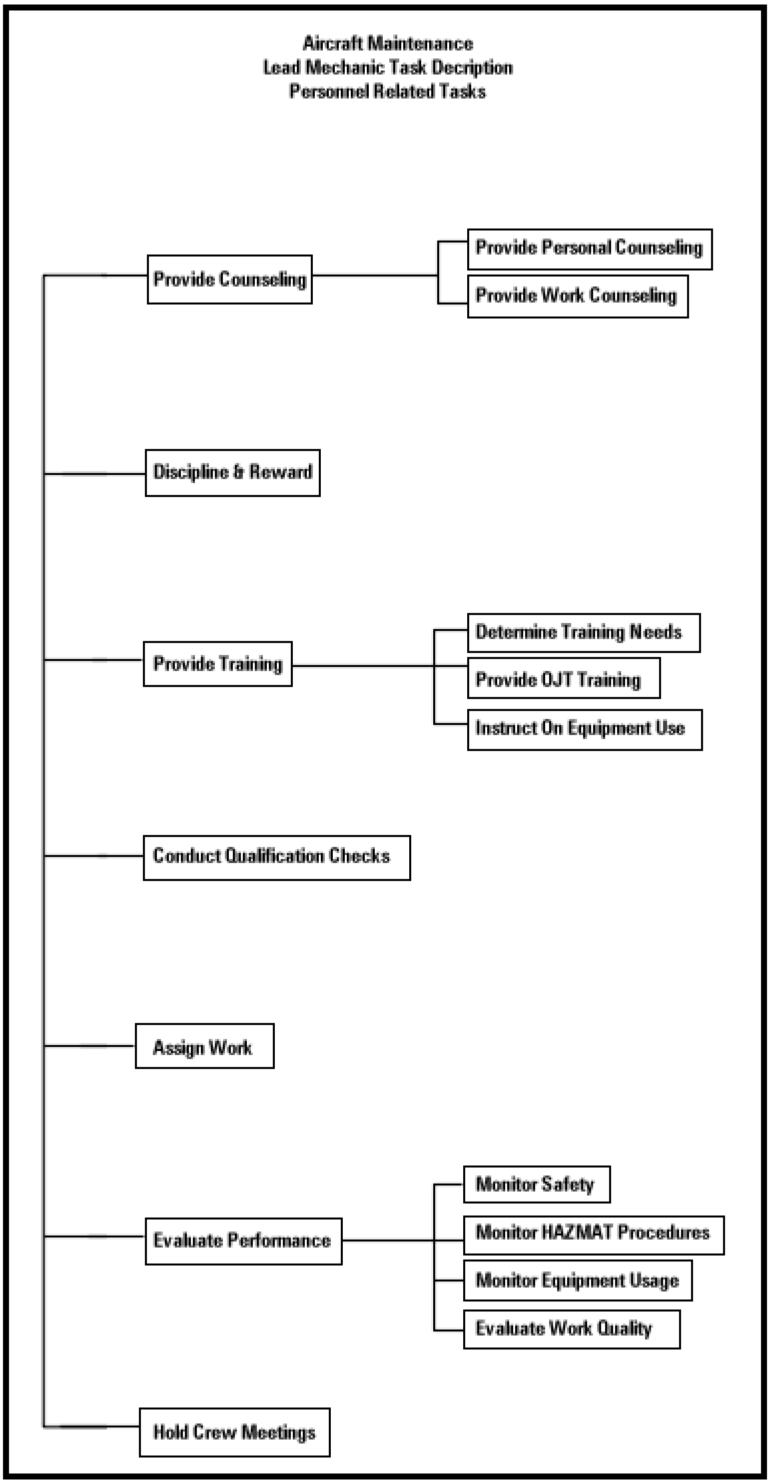
3.9.3 Appendix C Foreman - Operations Related Tasks



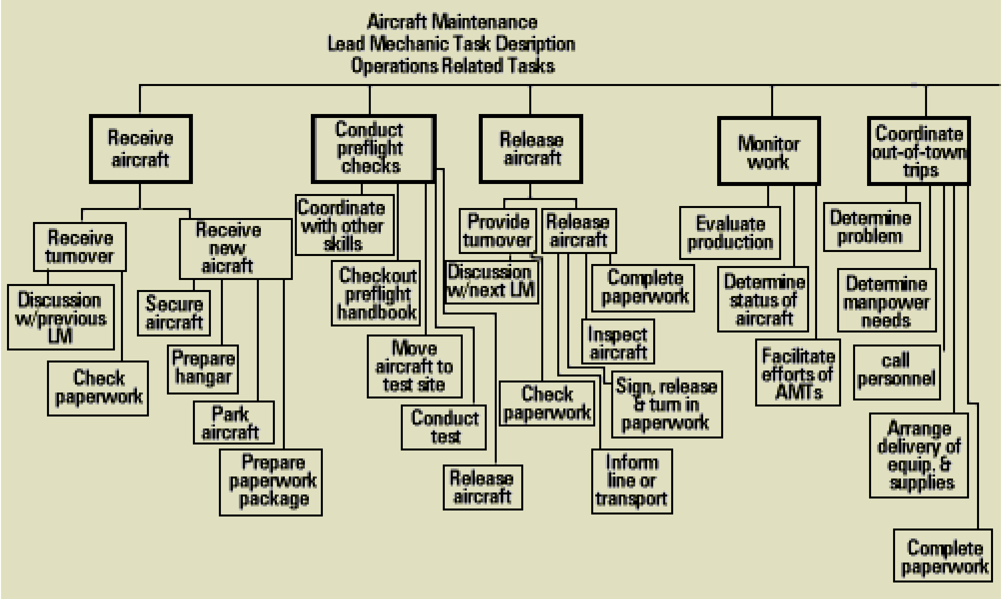
3.9.4 Appendix D Lead Mechanic - Administrative Related Tasks



3.9.5 Appendix E Lead Mechanic - Personnel Related Tasks



3.9.6 Appendix F Lead Mechanic - Operations Related Tasks



3.9.7 Appendix G - Task Analysis for Foreman

Task Description	TASK ANALYSIS – SUB-SYSTEMS: T	P	Com	D	Coor	I	SA	SUB-TASKS & OBSERVATIONS
ADMINISTRATION RELATED TASKS								
Process AMAs, HMAs and General Information	X	X		X				Receive information Review Post information
Post crew assignments		X						
Process logs	X	X	X	X	X		X	Initiate, update & complete shift log Initiate, update & complete hangar turnover log Receive, update & turnover OMIs
Report to general foreman/hangar manager	X	X	X	X	X			Report overtime used Report aircraft status

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	TASK ANALYSIS – SUB-SYSTEMS: T	P	Com	D	Coor	I	SA	OBSERVATIONS
Attend shift meeting	X		X	X	X	X	X	· Report A/C status · Discuss problems · Coordinate with other skills
Assume shift manager/hangar manager tasks as assigned	X	X	X	X	X	X	X	
Assign tasks to lead mechanics as required			X	X		X		· Assign selected foreman tasks · Assign non-operational tasks
Receive and perform tasks from management			X	X	X	X		
Approve payroll		X		X				
Monitor compliance with standards and procedures	X	X		X			X	

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	T	P	Com	D	Coor	I	SA	OBSERVATIONS
Perform miscellaneous office tasks		X		X				
PERSONNEL RELATED TASKS								
Discipline and reward		X	X	X		X		
Counsel lead mechanics and AMTs			X	X		X		
Conduct crew briefings	X		X	X				· Read AMAs and HMAs · Make announcements · Review procedures · Answer questions
Provide guidance, assistance and training to lead mechanics	X	X	X	X		X		
Conduct performance reviews		X	X	X		X		· Meet with individual AMTs and lead mechanics · Fill out and submit evaluation forms

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	T	P	Com	D	Coor	I	SA	OBSERVATIONS
Meet with labor representatives as needed		X	X	X		X	X	
OPERATIONS RELATED TASKS								
Receive aircraft	X	X	X	X	X	X	X	· Receive new aircraft · Receive turnover
Assign aircraft and personnel to lead mechanics	X		X	X	X	X		
Receive aircraft status from lead mechanic	X	X	X	X	X	X	X	· Record status · Discuss problems · Provide advice and guidance
Monitor work performance	X			X			X	· Receive notification · Assign lead mechanic · Handle situations as necessary · Follow up
Update crew and aircraft assignments	X	X		X				
Coordinate out-of-town maintenance trips	X	X	X	X	X	X	X	

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

3.9.8 Appendix H - Task Analysis for Lead Mechanic

Task Description	T	P	Com	D	Coor	I	SA	SUB TASKS & OBSERVATIONS
ADMINISTRATION RELATED TASKS								
Check and sign AMAs and HMAs	X			X			X	
Update time and attendance sheets		X		X				
Check in with foreman		X	X		X	X		
Schedule physical exams		X	X	X	X			
Assume foreman's tasks	X	X	X	X	X	X	X	
PERSONNEL RELATED TASKS								
Provide counseling	X	X	X	X		X		· Provide personal counseling · Provide work counseling
Discipline and reward		X	X	X		X		

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	TASK ANALYSIS							
	SUB-SYSTEMS							
	T	P	Com	D	Coor	I	SA	OBSERVATIONS
Provide training	X	X	X	X	X	X	X	· Determine training needs · Provide on-the-job training · Instruct on equipment use
Conduct qulification checks (equipment)	X	X	X	X		X		
Assign work to AMTs	X	X	X	X	X	X	X	
Evaluate performance	X	X	X	X	X	X	X	· Monitor and assure safety · Monitor and assure HAZMAT procedures · Monitor and assure proper equipment use · Evaluate and assure work quality
Hold crew meetings		X	X	X		X		

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	TASK ANALYSIS							
	SUB-SYSTEMS							
	T	P	Com	D	Coor	I	SA	OBSERVATIONS
Receive aircraft	X	X	X	X	X	X	X	·Receive turnover *Discussion w/ previous lead mechanic *Check paperwork ·Receive new aircraft *Secure aircraft *Prepare hangar *Park aircraft *Prepare paperwork package
Conduct pre-flight checks	X	X	X	X	X		X	·Coordinate with other skills ·Check out pre-flight handbook ·Move aircraft to test site ·Conduct test ·Release aircraft

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	TASK ANALYSIS							
	SUB-SYSTEMS							
	T	P	Com	D	Coor	I	SA	OBSERVATIONS
Release aircraft	X	X	X	X	X	X	X	·Receive turnover *Discussion w/ next lead mechanic *Check paperwork ·Release aircraft *Complete paperwork *Inspect aircraft *Sign release and turn in paperwork *Inform line or transport aircraft
Monitor work	X	X	X	X	X	X	X	·Evaluate production ·Determine status of aircraft ·Facilitate effort of AMTs

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Task Description	TASK ANALYSIS							
	SUB-SYSTEMS							OBSERVATIONS
	T	P	Com	D	Coor	I	SA	
Coordinate out-of-town maintenance trips	X	X	X	X	X	X		· Determine problem · Determine manpower requirements · Call personnel · Arrange delivery of equipment and supplies · Complete paperwork
Conduct administrative work	X	X	X	X	X	X	X	· Update foreman · Initiate, update and/or complete work log · Update aircraft log · Initiate, update and/or complete compliance sheets
Obtain parts	X	X	X	X	X	X		· Obtain part number · Order part · Receive part

T: Technical skills P: Procedural skills COM: Communication skills D: Decision making skills
COOR: Coordination skills I: Interpersonal relationships skills SA: Situation Awareness skills

Chapter 4
DOCUMENTATION DESIGN AID DEVELOPMENT

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4.1 INTRODUCTION

Studies of human error in reading and interpreting documents such as workcards have shown that substantial improvements are possible by incorporating human factors guidelines into document design. Error reduction through information design was addressed in this study by developing a design aid for documentation producers. With an airline partner, a focus group generated issues in the existing process for generating, testing and issuing of Engineering Orders (EOs). Parallel aspects of the project considered the physical design of the document and the organizational aspects of the procedures. A Documentation Design Aid (DDA) was developed using the technical literature on human performance in information transfer tasks. The DDA is available as a paper procedure document and as a Visual Basic (tm) computer program. User tests of the DDA gave positive results. The partner airline is acting to incorporate parts of the DDA into its electronic documentation systems and to revise its procedures for designing, prototyping, and using Engineering Orders (EOs).

4.2 BACKGROUND: DESIGN OF JOB INSTRUCTIONS

For a number of years the airline industry has been seeking ways to reduce errors, particularly human errors, in its operations and maintenance activities. During this time the Federal Aviation Administration/Office of Aviation Medicine (FAA/AAM) has been funding research and development to address human error. The 1995 Safety Summit declared human error to be a major concern, and reemphasized the importance of aircraft maintenance errors on the list of priorities. One error-prone area chosen for study early in the FAA/AAM program was the information environment of the people performing inspection and maintenance activities.[1] In particular, on-site data collection found that much of the paperwork used to control the hangar floor activities did not follow good human factors practice.[2]

Studies aimed specifically at paperwork improvement were undertaken with one airline partner. The first study[3] took existing work control cards (workcards) and determined their specific problems from task observation, interviews with AMTs and inspectors, and survey data. These findings provided the structure needed to develop guidelines for workcard design, compiled from the human factors research literature. Based on those guidelines, new workcards were designed and tested on inspectors performing C-check wing inspections of a DC-9-30. The new workcards were a significant improvement in terms of readability and usability.

Following this demonstration of the improvements possible in workcards from following human factors guidelines, the next logical step of producing computer-based workcards was taken.[4] These workcards incorporated all of the guidelines used for improved paper-based workcards, while adding specific recommendations on human interface guidelines for computers. Again, the new workcards were compared with existing workcards, this time using a nose landing gear inspection task on DC-9-30. In this study, however, there were three versions to compare: the existing workcard, the improved paper-based workcard, and the new computer-based workcard. The results showed that the computer-based system was a significant improvement over the existing paper-based workcards. However, an important finding was that about 80% of the total improvement was seen with the improved paper-based workcard. Clearly, getting the information correctly designed, sequenced, and presented is of utmost importance in improving paperwork.

These improvements can result in lower rates of paperwork errors. Drury[2] was able to collect airline data which showed a high error rate (2.5%) on workcard items which did not meet the Patel, Drury and Lofgren[3] guidelines, compared with a zero error rate for items which met the guidelines. If each item on a workcard of 28 items has an error rate of 2.5%, then 50% of the workcards would have at least one error, clearly an unacceptable outcome in airline operations or maintenance. Workcards are used by people regularly under nonoptimal environmental conditions, often with time stress, so that any physical means of reducing errors, such as better workcard design, is particularly cost-effective.

Other recent work on the information system/Aviation Maintenance Technician (AMT) interface has included:

- studies of paperwork errors in the engine overhaul facility of one airline partner[5]
- evaluation of Simplified English in workcards at a number of airlines[6]
- design of shift change logs at another airline partner[7]
- redesign of a logbook by the AMTs at another airline

4.3 PROJECT OBJECTIVES

Now that we have demonstrated the use of human factors guidelines to redesign work documentation for higher usability and less errors, these techniques need to be made available to the industry in a form which encourages their regular use. The current project was undertaken to compile a comprehensive and valid set of documentation guidelines, and design convenient interfaces to these guidelines for potential users. Also included in the project was a test of the usability and effectiveness of the guidelines.

An airline partner agreed to provide resources for carrying out this study. In return, they are able to use the study as part of a larger investigation and change process focused on one particular type of documentation -- Engineering Order (EO). Because the airline partner, like many in the mid-1990s, had an ongoing human factors program, this project could make use of their current human factors methodology, for example in the use of multifunctional teams to investigate, recommend and implement changes.

Thus, the project as undertaken had two complementary objectives:

1. To provide the FAA and the airlines with a developed and tested job aid to improve documentation design.
2. To provide the airline partner with model application of human factors to the process of design, production and use of documentation.

The project was structured so that the two objectives could be pursued in parallel, with successive refinements in the job aids being accompanied by progress through the change process at the partner airline.

4.4 METHODOLOGY

Because of the parallel objectives for the FAA and the airline partner, there were two closely interleaved aspects of the methodology, one primarily technical and one primarily behavioral.

The technological methodology consisted of accessing the research literature on document design, reviewing it critically, and incorporating these findings into the successive versions of the Documentation Design Aid (DDA). Because most of the research findings would be applicable to all documentation, the refinements to DDA were aimed at emphasizing the specific requirements of aircraft maintenance documentation.

For example, Tinker[8] showed that using black ink on white paper improved reading speed by 10.5% and reading comprehension by 8.6%. However, almost all aircraft maintenance documentation is already in "black ink on white page" format so that this issue rarely arises in practice. In contrast, the finding that use of upper case font (all capitals) reduces reading speed by 14%[8] is of great relevance as capitals are often used where emphasis is desired in work instructions.[3] In terms of DDA design, the finding on ink color should receive less emphasis than the finding on use of upper case font.

This project is not the first to bring together human factors research findings and good practice into codified guidelines. Simpson and Casey's[9] *Developing Effective User Documentation* come from the nuclear power industry, while Wright's[10] *Information Design* was based on requirements for design of forms and documents for use by the general public. There has even been software written, e.g., the Communication Research Institute of Australia's[11] *Forms Designer*, to help users design effective forms. A monthly newsletter (*Procedures Review*) is devoted entirely to design of work control documentation. As a final example, the guidelines of Patel, et al.,[3] and Patel, Prabhu and Drury (1992)[13] on paper and computer information design, respectively, were most closely adapted to the aircraft maintenance environment. Section 4.9.1 provides a bibliography of the major sources used to develop the DDA, and is a useful secondary source for further document design information.

The second aspect of the methodology was behavioral. This was comprised of all the work with the partner airline to tailor the documentation design aid to practical airline needs. Thus, while the compilation of the literature was ongoing, maintenance management of the partner airline met with SUNY Buffalo and internal human factors representatives to provide support and direction for the project. They approved the use of a team (or focus group) to investigate documentation issues within the airline, and to recommend specific actions to reduce human error and its impact in the documentation process. This management group suggested the idea of the DDA as a "workcard for workcard," i.e., a design aid arranged in steps with sign-offs after each step, whose use would ensure that each document was well designed. Such a product reemphasized the need to develop both paper-based and computer-based versions of any job aid produced in this project.

A team was formed with the SUNY Buffalo and airline human factors personnel and included representatives of each of the following stakeholder groups:

1. Producers of Documentation
    - Engineers and technical writers who control the technical content of work instructions and who control the process of transforming the content into a work instruction document.
2. Users of Documentation
    - Mechanics (AMTs), inspectors and first line supervisors who must use the documentation to perform the work to ensure compliance with all necessary standards.
    - Maintenance records operators who must check the completed documentation for completeness and accuracy.
3. Managers
    - Those responsible for the processes of ensuring that correct documentation is available, that the work is performed correctly, and that correct records are maintained.

This focus group acted as the main forum for interchange of ideas throughout the project. At the management meeting a suggestion was made to focus on the process for developing and using Engineering Orders (EOs) and Campaign Directions (CDs) to provide a sensible scope of work. This suggestion was taken up by the focus group, and in fact Engineering Orders became the true focus of the project. EOs are special work control cards used where a new aircraft modification is required on some or all of the aircraft in a particular fleet. Often they arise from regulatory directions based on recently discovered problems, or from manufacturer-initiated upgrades to aircraft. In format, EOs have great similarities to CDs and workcards. CDs are used to control new and often unique inspection and maintenance processes. The more repetitive tasks are covered by workcards. Because of this, EOs represent the initial designs produced by engineering and technical writers, often under severe regulatory time pressure. The tasks they detail may also be subject to the same time pressures. Time pressure is a well documented stressor in human factors, leading to altered task strategies and increased error rates as well as to operator stress.[14] Thus improvement of EOs should give immediate payback under conditions where errors are *a priori* more likely to occur. Also, any design aid must be designed to be usable by engineers and technical writers under these same time pressures, ensuring a stringent test of its usability.

The focus group helped identify issues beyond the physical design of documents (such as EOs) which could be affecting usability and error rates. These included the design process, how EOs are field tested, control of the revision process, and specific confusions about the sign-off process. In any project on EOs such issues need to be tackled in parallel with development of the DDA to ensure that changes are made and implemented throughout the system.

The outcome of the initial meetings with management and the focus group was a better defined project: produce paper-based and computer-based design aids which help ensure that human factors guidelines are followed to reduce errors in the design, development, and use of Engineering Orders. We have used the term "Human Factors Good Practice" to connote recommended good procedures, whether they arose from standards, guidelines, or the research literature.

4.5 RESULTS

4.5.1 DDA Development: Content and Structure

During the compilation of literature on document design, a number of points emerged. First, while there was often agreement among the sources about recommendations, in some instances there were differences. Where we found differences, we chose the recommendation which was most closely related to aviation maintenance. For example, Tinker8 showed that 60.5% of higher level readers preferred a double column layout text format. In contrast to this, Hartley9 showed that using double column layout or single column layout does not make a large difference for higher level readers in terms of reading comprehension and reading speed while it makes a difference for lower level readers. However, as almost all aircraft maintenance documentation is already in a single column layout, we defined the guideline to favor single column layout. Second, in a few particular cases the research findings contradicted the practices codified for aviation maintenance in the ATA-100 document.3 In ATA-100 standards, it is suggested to use all capital letters in caution sections, but this contradicts the findings presented by Tinker8 about lower case vs. capitals. When this occurred, ATA-100 recommendations were replaced by those supported by research findings. Third, the SUNY team and the focus group thought it was important to go beyond just stating recommended good practice to include both examples and the reasons why the recommendation was made. With these additional aspects incorporated, the final DDA could be used both as a rapid design checklist and as a learning tool. The aim was to move beyond what Rasmussen15 has termed "rule-based performance" to the higher level of understanding characterized by "knowledge-based performance."

To turn the final set of documentation design findings into a usable design tool required a number of iterations, each with feedback from the task force at the partner airline. The initial DDA structure followed, which was developed for workcards by Patel, et al.3 This structure was expanded to include our newly discovered findings. In successive stages, this set was edited and its structure changed to conform to expected use by documentation designers. Table 4.1 shows the final structure, which starts with overall considerations of information content; i.e., what needs to be in a document and how it should be organized into a logical sequence. Next come considerations of readability, with the more mechanical aspects such as typeface, page layout and how to provide emphasis. Writing considerations come next, i.e. how to turn the document content into sentences and paragraphs which can be read and understood easily. Finally, the section on other organizational issues covers a recommended process for ensuring early and continuing user input into the document design. The final aspect of our design of the DDA was to insure that its form indeed meets our standards. Thus, the human factors best practice defined in the guidelines was applied to the DDA itself. During this iterative design process, the paper version of the DDA passed through many forms. This ensured that by the time coding of the computer-based version was begun, the DDA content was designed with the user in mind.

Table 4.1 Classification Scheme for DDA

1.0	**Information Content**
1.1	User-Centered Design
1.2	Logical Content
1.3	Task Sequencing
1.4	Headings and Levels
1.5	Notes/Warnings
2.0	**Information Readability**
2.1	Typographical Layout
2.1.1	Page Size
2.1.2	Page Layout
2.1.3	Justification
2.1.4	Paragraphs and Indentations
2.1.5	Spacing
2.1.5.1	Vertical Spacing
2.1.5.2	Horizontal Spacing
2.1.6	Typeface
2.1.7	Type size

4.5.2 DDA Development: Computer Considerations

In moving to a computer-based design aid, two considerations were important: the structure of the DDA interface and the choice of hardware/operating system combination. First, presentation of information need not be restricted to the linear mode forced by a paper-based system. As noted in Patel, et al.,3 for workcards themselves, information can be given in a hierarchical manner, where the user starts at a high level of abstraction and by successive menu choices reaches the required information as one particular branch of the tree structure. Alternatively, the user can move between branches directly, if the branches are constructed as interconnected nodes and a suitable program written for node-to-node movement. This branching structure is the basis for hypertext documentation systems, familiar to users in "Help" facilities on a PC, or as browsers on the World Wide Web. Patel, Drury and Shalin (1997 in press)16 showed how to take advantage of the cognitive structuring of a domain by expert users to help novices reach required hypertext information more rapidly. When there are enough expert users of DDA, this may become a useful option. A final way to access computer-based information is through a keyword index, such as those used under "search for Help on:" in Windows(tm) Help systems. The final version of the DDA supports all of these modes of use.

The second consideration is the issue of the appropriate hardware platform and operating system. Because of widespread industry use and FAA project requirements, the decision was made to write for Intel micro processors (X486 and above), running MSWindows (3.1 or above) with mouse support. Programming was in MS Visual Basic for consistency with other applications produced by SUNY Buffalo and Galaxy Scientific Corporation for FAA/AAM. With Visual Basic and Windows, it is possible to have the DDA reside in one window while working on a document in another window. In fact, the structure of the final DDA was made simple enough that users could produce equivalent code for themselves in other operating systems such as MAC-OS or UNIX.

4.5.3 Interface and Functionality of the Computer-based DDA

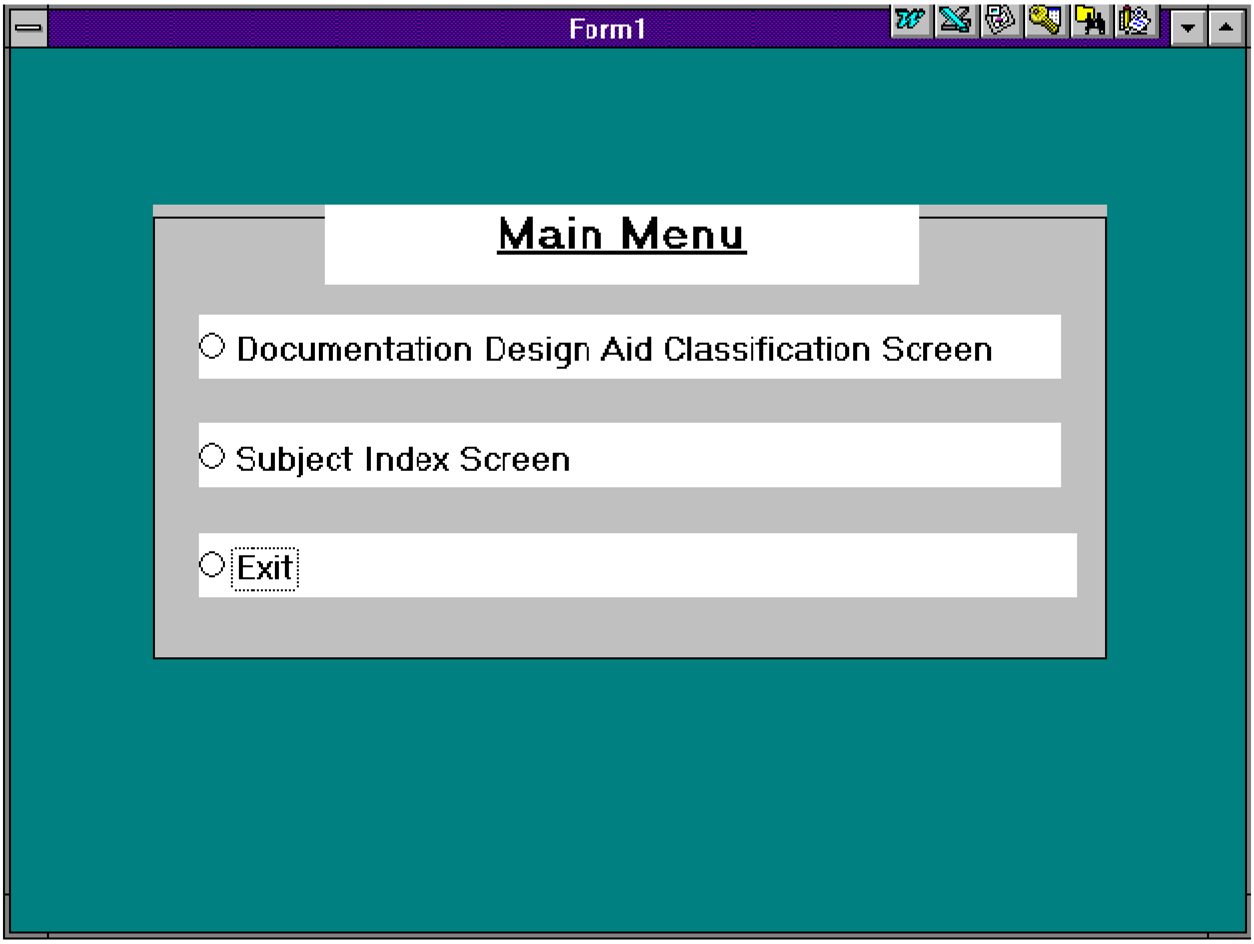


Figure 4.1 The Main Menu Screen of the Final DDA Program

The final DDA program is shown as a set of figures (Figures 4.1- 4.7). The user is first given the Main Menu screen (Figure 4.1) where a choice is made between the two major user modes: classification and index. The classification system (Figure 4.2) is a hierarchical table of contents matching the major and minor headings of the hardcopy document (Table 4.1 and Section 4.9.2). The index system gives an alphabetical list of contents (Figure 4.3). An experienced user will probably use the classification system; however, if the structure of the DDA is not well known (or is forgotten), the index would be more appropriate. Note that selecting an item from the index leads to exactly the same "Human Factors Good Practice" screen as could be accessed from the classification system.

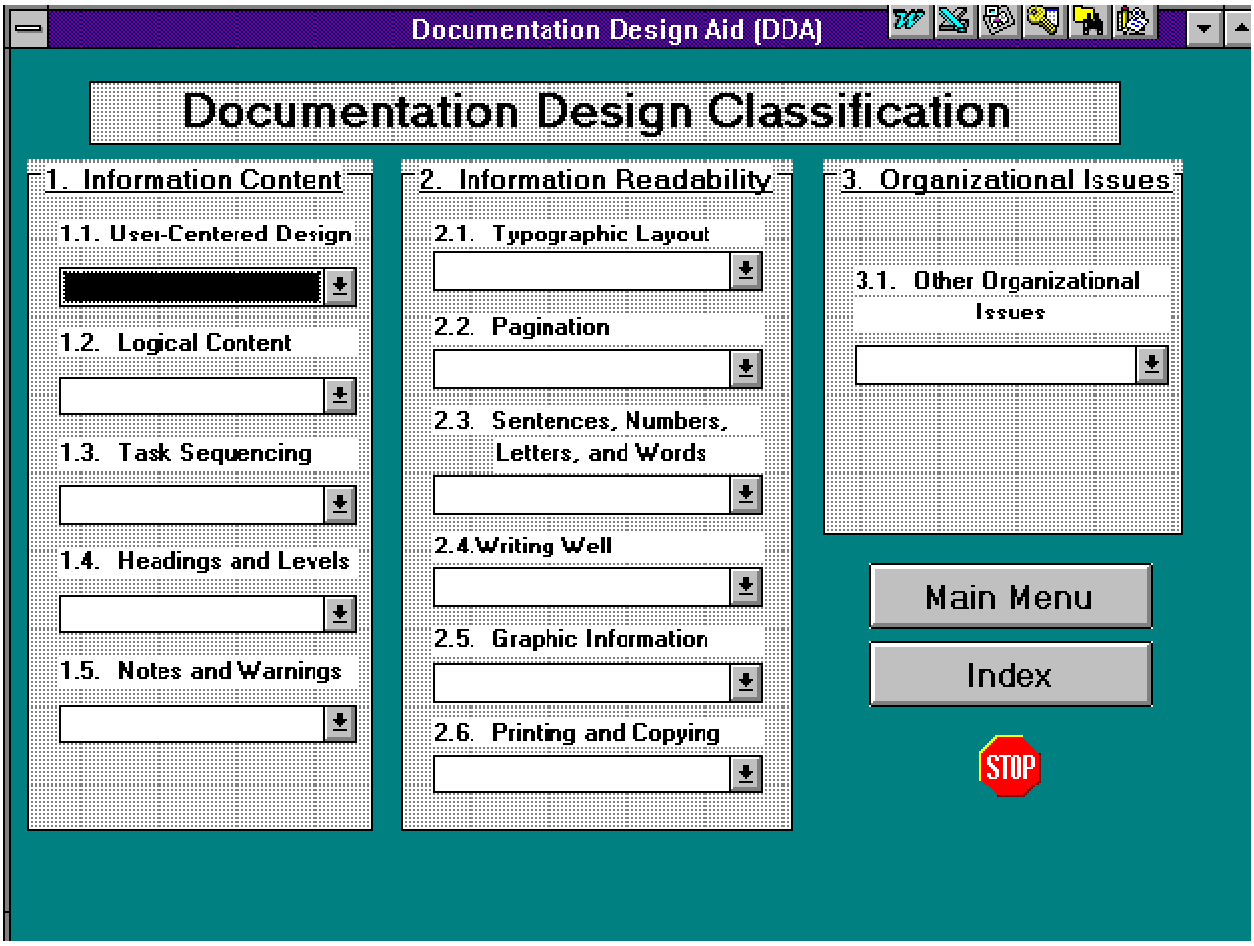


Figure 4.2 Documentation Design Aid Classification Screen

Selecting an item on the classification system, for example "2.1: Typographic Layout" on Figure 4.2, displays a pull-down menu of the end items under this heading (Figure 4.4). Selecting an end item, such as "Responses" on this pull-down menu, supplies the main screen of desired information -- the "Human Factors Good Practice" screen (Figure 4.5). This tells the user the basic rules for good practice, i.e., for designing low-error documents.

At this point, the user can select one of the buttons on the lower row to obtain more detail on each rule. In Figure 4.5 the rule on "Not Required" boxes has been selected. Pressing "Example" gives correct and incorrect examples (Figure 4.6). Canceling this box by selecting "OK" returns the user to the "Human Factors Good Practice" screen (Figure 4.5). Selecting the "Why?" button here brings up a box showing reasons from the literature supporting the practice. Figure 4.7 gives a reason for the margin recommendations under Page Layout as an example. As noted earlier, this facility helps the user understand that the guidelines are not arbitrary preferences, but the result of measurements of human characteristics.

The user can terminate the DDA program by using the "stop" button, or leave it active but reduced to an icon by clicking on the down-arrow button in the upper right corner of the DDA window, conforming to Windows stereotypes.

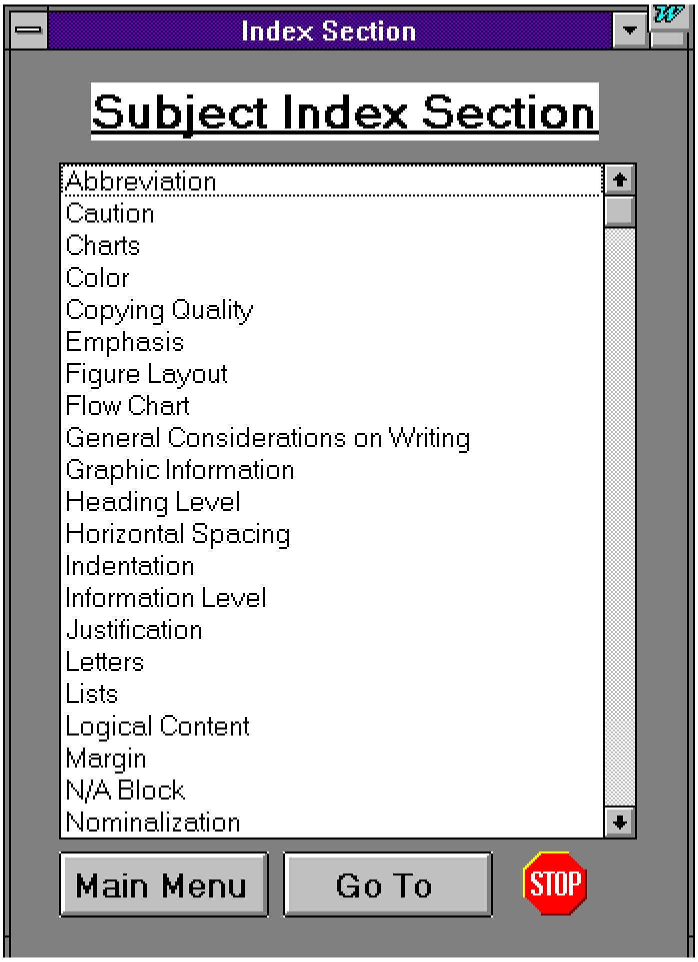


Figure 4.3 Subject Index Screen

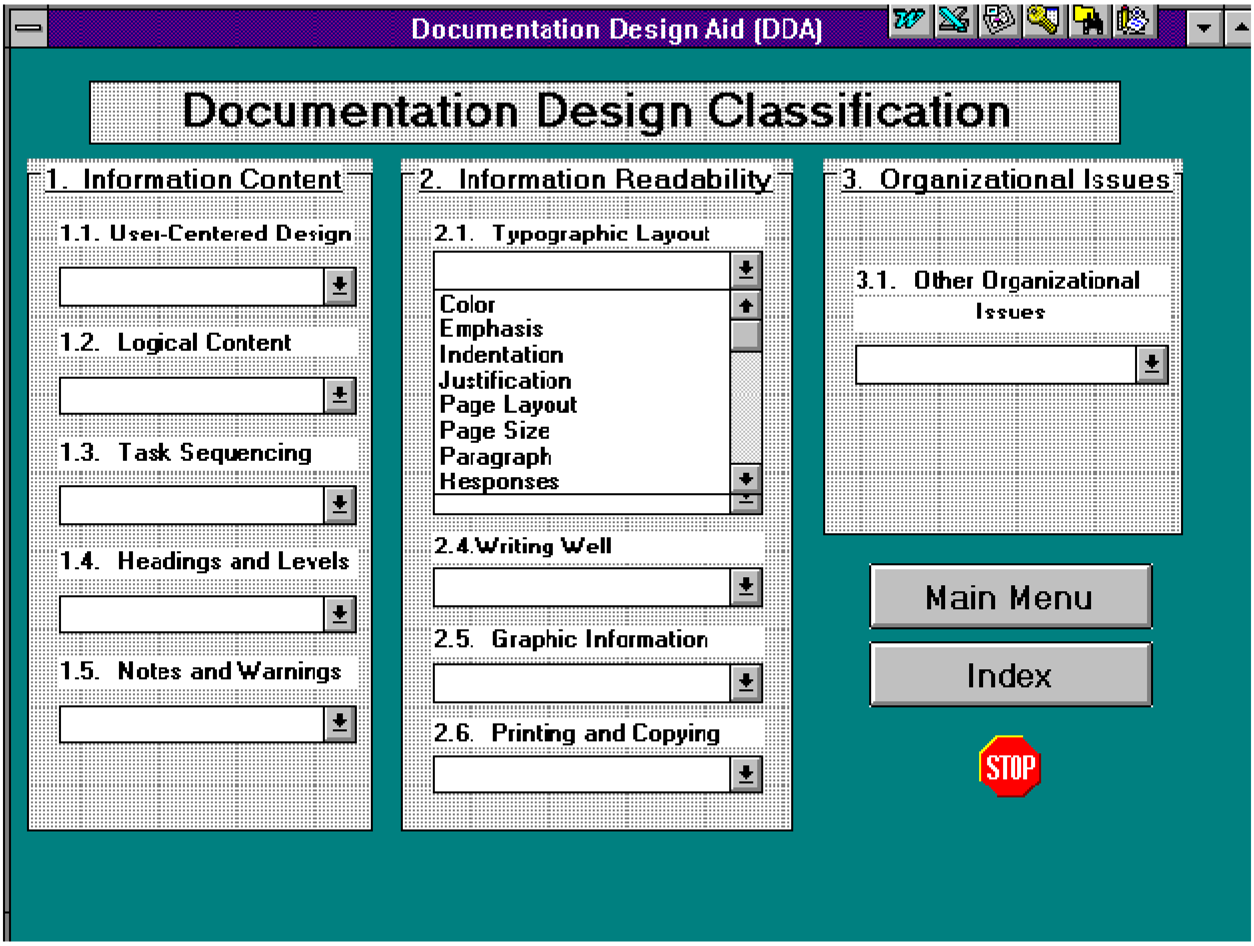


Figure 4.4 Pull-Down Menu for "2.1 Typographic Layout"

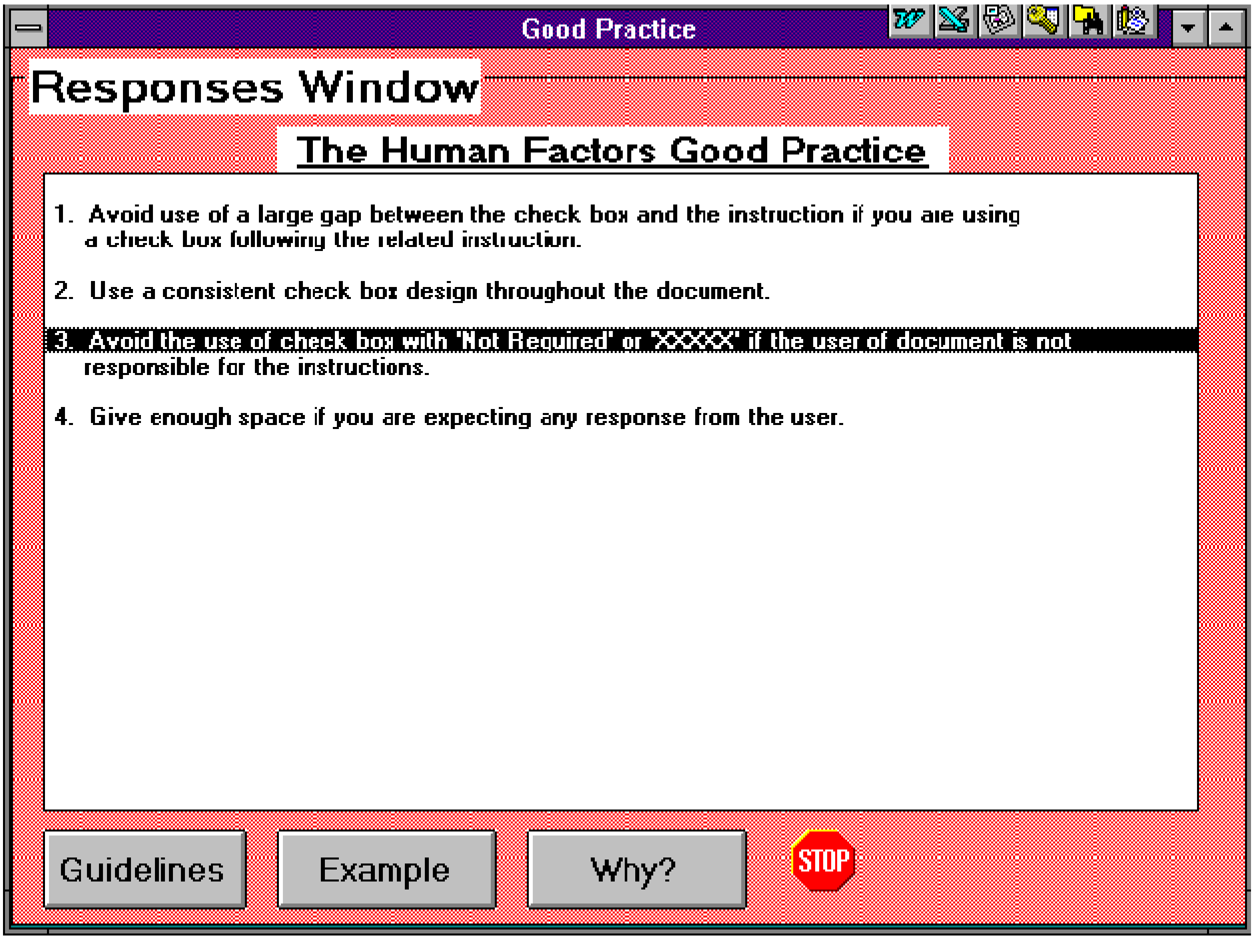


Figure 4.5 Human Factors Good Practice Screen for "Responses"

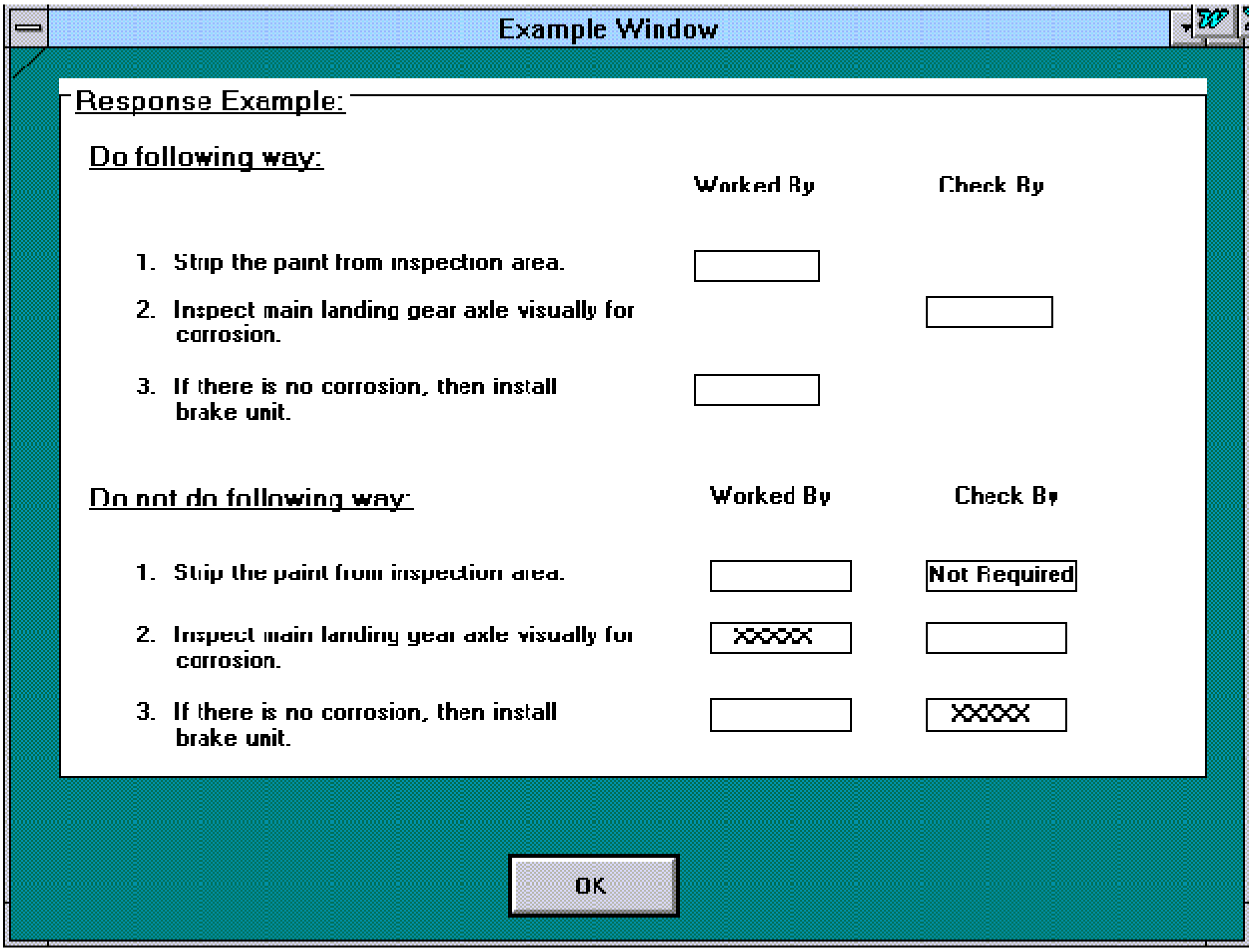


Figure 4.6 Example Screen for "Responses"

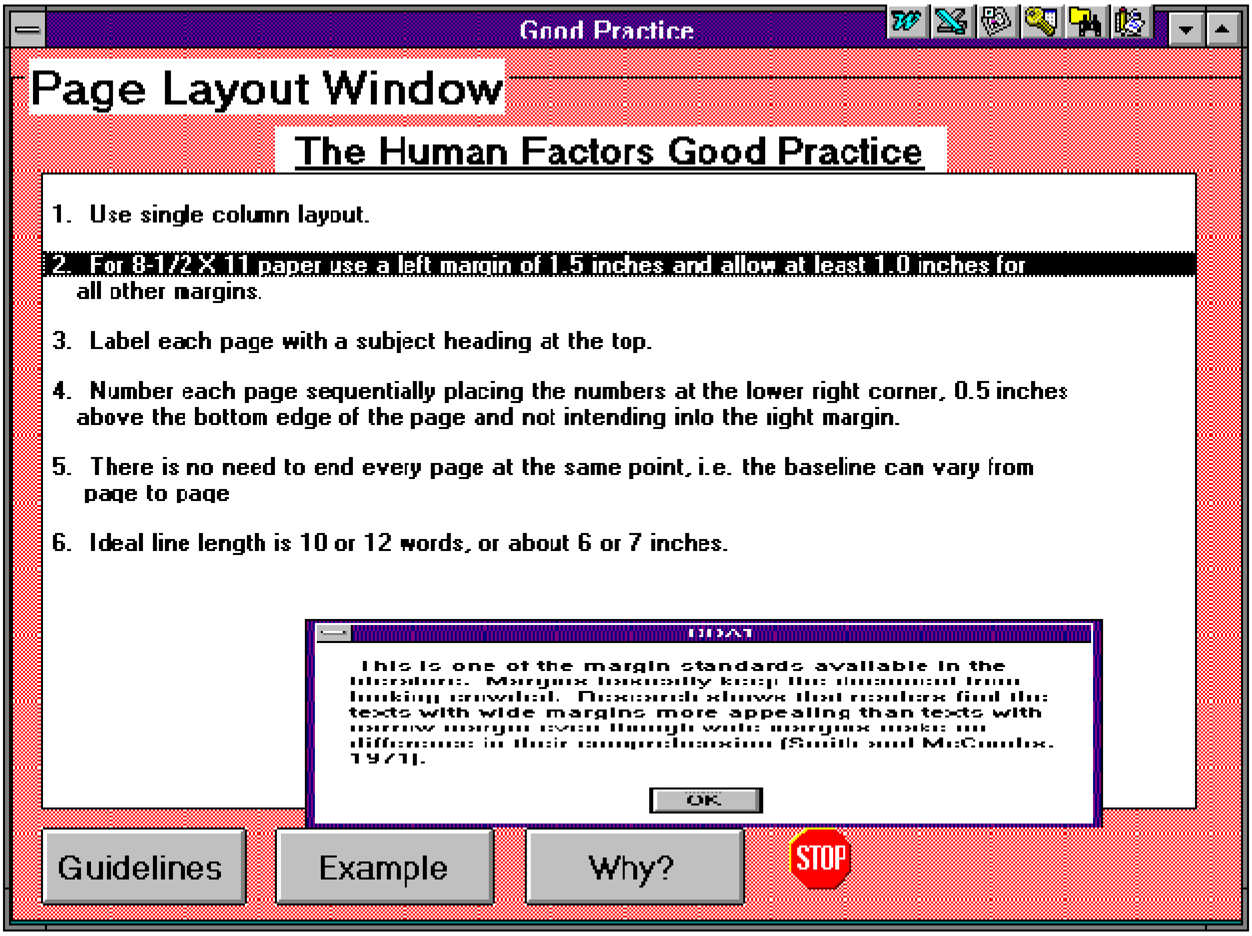


Figure 4.7 Reason Screen for "Page Layout: Margin"

4.5.4 Analyzing the EO Process

At the first meeting of the focus group (April 1996) a round-robin process was used to ensure that all present could raise issues about documentation design and the process by which EOs are generated and performed. This meeting provided over 70 issues of concern to group members. The issues ranged from the very general ("Need to encourage mechanics to take more responsibility for their work") to the highly specific ("Not Applicable" N/A policies are confusing in procedures which branch or have conditional statements."). All of the issues were listed, with no discussion or critique by the team. This list of issues was classified by the SUNY team and similar issues were combined. The final structured list is shown in Table 4.2.

Table 4.2 List of Original Issues Generated by Focus Group

Topic	Description	Number of Issues
1. Confusion about items marked "Not Applicable"	How should mechanics use "Not Applicable" (N/A) or "Previously Complied with" (PCW)?	7
2. Form design	e.g. Should there be a flow chart on EOs? Can we move some management material to end of EO?	10
3. Review of EOs		18
3.1 Review sheets	e.g. Does the review sheet ever reach a mechanic?	(3)

3.2 Other review processes	e.g. Does every EO need to go through review process?	(8)
3.3 Feedback forms	e.g. Difficulties in faxing feedback forms	(5)
3.4 Revisions	e.g. Can we revise just parts of an EO?	(2)
4. Development and distribution of EOs	Training of engineers to write EOs, time pressure to complete EOs.	13
5. Completion of EOs	e.g. How do we ensure a sensible sequence of tasks? Scheduling of EO work?	3
6. Other issues	e.g. Too much paperwork, how to ensure mechanics are careful.	3
Total		**54**

Issues listed in Table 4.2 formed the basis for improving forms design (Topics 1, 2) and for mutual understanding of the EO process by the focus group. Many members were unaware of how the EOs system affected other stakeholders, so that the mutual understanding within the group was of great help in finding appropriate interventions. Following this meeting, the SUNY team flowcharted the EO process, using both the airline's General Maintenance Manual and group knowledge. The above list of issues became the basis for the partner airline's changes to the EO process.

While these process-oriented issues were being considered, two representative existing EOs were selected for progressive redesign using the DDA guidelines. One was quite simple, the other more complex. Both had resulted in some paperwork errors, but were considered to be neither very good nor particularly poor designs. The *Main Landing Gear Wheel Axle Corrosion and Crack Verification* for a large transport aircraft will be used in this report as an example.

In each session with the focus group, specific points about the latest version of this EO were discussed and recommendations made for possible improvements. The SUNY team then modified the EO and distributed the revised version to the group, who analyzed the changes in time for the next meeting. It should be noted that the focus group took its mission very seriously and found time to make many insightful comments at each iteration. During this process, one SUNY team member (A. Sarac) worked with one focus group member (an inspector) in performing the EO. The inspector led the SUNY team member through each step, showing how to recognize each part on the aircraft, how to perform the procedure and how to make the correct written responses.

Midway through the project (after two redesign iterations), a more design-specific list of issues was generated by the focus group using the round-robin technique. These helped to further structure the EO design. They were later classified as Table 4.3.

Table 4.3 List of Design Issues Generated by Focus Group

Topic	Description	Number of Issues
1. Sign-off design	How can we ensure sign-off boxes are not missed?	10
2. Ordering of steps	How can we ensure a logical task sequence?	1
3. EO logical structure	How can we present the logic of the EO to the user?	4
4. Managing the EO process	How can we ensure AMT input into each EO?	11

5. Consistency of design	How can we achieve consistency across EO writers?	2
6. Layout/design of EO	Can some material be eliminated from EOs?	6
7. EO wording	How can we implant Simplified English in EOs?	3
8. Backup information	Should we ensure the EO is self contained?	1
Total		**38**

Typical issues addressed in the EO design process were:

1. Many items were moved from the front of the EO to the back as they are not needed by the main user.

2. A flowchart was placed at the beginning of the EO to show the logical ordering of steps and to indicate any branching. To help users branch correctly over a number of steps not required (e.g., because no corrosion was found), each box on the flow chart contained the step number in the procedure.

3. For better control of the work on the hangar floor it was agreed, that when an EO required the same task on both sides of the aircraft (or both engines), a separate EO should be issued for each side. This would prevent errors when tasks were interrupted or carried across shifts.

4. Graphical material was integrated with the text steps and sign-off boxes to ensure compatibility and availability of the graphics. As airlines move into electronic publishing, this becomes a feasible alternative to referencing source documents which must be copied and attached.

5. The original layout of task steps used vertical and horizontal lines forming "boxes" around each task step and sign-off area. This was changed to present the task steps in an open layout and only to include sign-off boxes where they were required. Besides being easier to use, this meant that sign-off boxes could be included exactly where they were needed. With a "box" layout, there is always a sign-off box for both the AMT and the inspector at each step. Where one is not needed, this is indicated by printing "XXXX" or "N/A" in the box. Where neither is needed, e.g. for a Caution, both boxes must be printed with one of these notations. With the more open layout, such unnecessary boxes are omitted so that there is a much cleaner indication of who needs to sign off each step. This should also make missed sign-offs by the AMT and/or the inspector much easier to detect during and after task performance.

6. Where a procedure contains a conditioned statement, the user must branch to different steps depending upon whether the condition is true or false. This means that the user must often sign many unnecessary steps as "N/A" in order that all steps are seen to be completed. Missing "N/A" indications are known to be quite error-prone. An alternative method was devised to make the process less error-prone, and incidentally easier for the user. Where there are a large number of "N/A" after a branch, single sign-off is made using a boxed step (Figure 4.8).

Following this step, the shape of subsequent sign-off boxes changes from a rectangle to an oval until applicable steps resume, when it changes back to a rectangle. The user can make a single sign-off at the boxed step, and then not have to "N/A" the ovals following this step. Again, the current move to electronic publishing gives technical writers more choices in the shaping and formatting of boxes, than were available under older documentation systems.

7. Choice of words and sentence structure for any document should now follow the rules of Simplified English for comprehension and consistency. Chervak, Drury and Ouellette (1996)6 showed that Simplified English led to lower error rates, particularly for complex documents and for nonnative English speakers. Parts of the EO used throughout this project were rewritten in Simplified English to demonstrate its utility. It was found that the document was indeed simpler, and in fact shorter, than the original version. In the future, it will be important to interface the DDA with the existing body of knowledge on Simplified English, particularly the glossary. This will make Simplified English more easily accessible to those who must produce technical documents.

To determine whether the revised EO met the needs of the focus group, changes made to the EO were checked off against the list of design issues raised by the group. In effect, the list of design issues became a design checklist for the EO design part of this project. As each issue was addressed, it was incorporated into the document design guidelines of DDA, to make that job aid more relevant to the design of procedures.

NOTE: If there is no evidence of corrosion found, then

-Stamp this signbox to indicate Step 13 thru 21 as "N/A". ☐

-Skill Step 13 thru 21.

-Go to Step 22.

Figure 4.8. Suggested "N/A" Block Structure

4.6 EVALUATING THE DDA

With any newly developed job aid two criteria must be established:

1. *Usability*: Is the job aid usable for its intended purpose by intended users?

2. *Effectiveness*: Can intended users perform their job better with the job aid?

Logically, evaluation of usability must precede evaluation of effectiveness. Usability testing of computer-based tools has become a standard human factors evaluation technique.17 Its aim is to ensure that the product can be used by its intended users, and that any problems of human use are found early in the product development cycle. A small sample of intended users are given appropriate briefing/training in use of the product, and then must use it in a typical task.

Here, the task was to modify an existing EO to conform to the human factors guidelines embedded in the DDA. A relatively short EO (23 pages) was chosen as providing an appropriate test of the usability of the DDA without requiring inordinate amounts of partner airline resources. An EO was chosen which contained a number of shortcomings when compared to human factors good practice. In fact, the EO was recently used at the partner airline, and some errors had occurred in the completed documentation. The sample group of six potential users, engineers, and technical writers at the partner airline was divided randomly into two groups. Half used the paper-based DDA while the remainder used the computer-based version. In this way, we could test the critical "first use" of each job aid to determine how well it could be expected to work in other airlines. Each user was video taped throughout the briefing and use of the DDA to determine where hesitations, false starts, and errors were made. Usability was measured not only from the video tapes but also from a series of rating scales completed by each user after performing the task. Times were measured for the preliminary briefing and learning, for taking a quiz on the briefing to ensure understanding, and finally for performing the EO modification task.

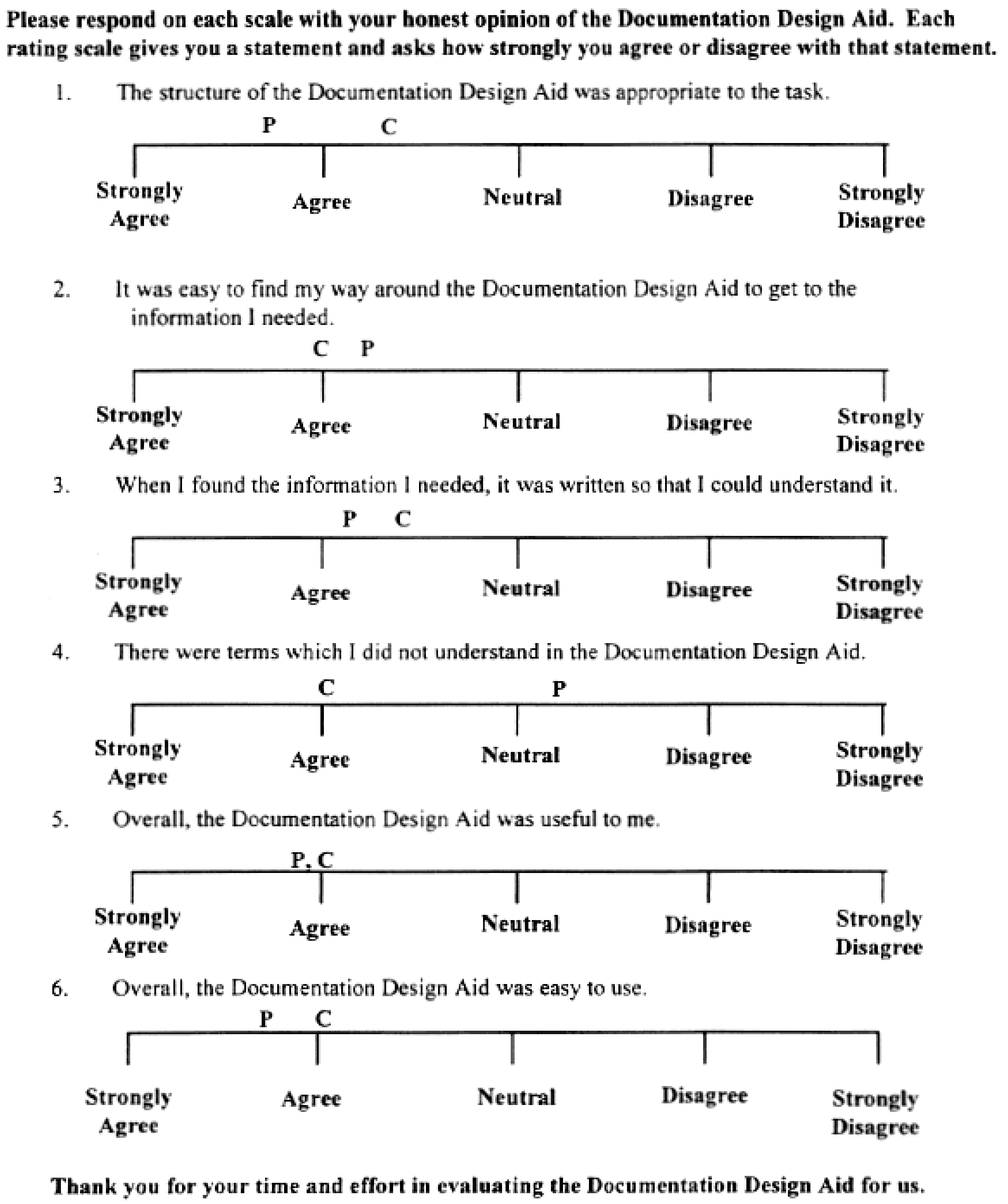
Effectiveness was measured by comparing the changes to the EO made by each user to the master list of 34 changes made by the SUNY team and members of the focus group. These "expert users" had had several weeks to study and amend the test EO, so that almost all of the changes required for it to conform to human factors good practice could be expected to have been found. Effectiveness was measured by the number of (correct) changes made to the EO in relation to the total number of possible changes. Where a single change was expected to apply to the whole document, as in "move all sign-off boxes to the right edge," this was counted as one change, not as one change per sign-off box. Changes were marked by users on the EO itself, and in case of doubt, the video tape was consulted to help determine the user's intentions.

Results of the evaluation were analyzed using the MINITAB(tm) program to compare the computer-based and hard copy versions of DDA. Comparisons of the times for the two versions showed no significant differences between versions, except for the times on the quiz where the number of questions differed between the two versions. When time per question was calculated, there was no significant different between versions.

As can be seen from Table 4.4, the DDA took less than 20 minutes to learn well enough to begin the task including completing the quiz. Modification of a 23-page EO took about one hour for first time users.

Documentation Design Aid Usability Evaluation Scales

Please respond on each scale with your honest opinion of the Documentation Design Aid. Each rating scale gives you a statement and asks how strongly you agree or disagree with that statement.



Please respond on each scale with your honest opinion of the Documentation Design Aid. Each rating scale gives you a statement and asks how strongly you agree or disagree with that statement.

1. The structure of the Documentation Design Aid was appropriate to the task.

P C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

2. It was easy to find my way around the Documentation Design Aid to get to the information I needed.

C P

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

3. When I found the information I needed, it was written so that I could understand it.

P C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

4. There were terms which I did not understand in the Documentation Design Aid.

C P

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

5. Overall, the Documentation Design Aid was useful to me.

P, C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

6. Overall, the Documentation Design Aid was easy to use.

P C

Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree

Thank you for your time and effort in evaluating the Documentation Design Aid for us.

Figure 4.9. Usability Evaluation Scales. "P" represents mean rating for paper-based DDA and "C" represents mean rating for computer-based DDA.

Table 4.4 Analysis of times in usability tests

Measure	Time, Paper based DDA	Time, Computer based DDA	Probability of Difference
Briefing/Learning Time, min	**7.7**	**6.7**	**0.79**
Quiz Time, min	**9.0**	**13.3**	**0.03**

Quiz Time per Question, min	**0.75**	**0.60**	**0.22**
Task Completion Time, min	**59.0**	**61.7**	**0.42**

Effectiveness was measured by comparing the changes found by the users to those found by the SUNY team for each version of the DDA. Where a correct change was found by the users, this was scored as a "hit," where an incorrect change was found, this was counted as a "false alarm."

Because we asked for a reference in the DDA for each change, we could count the number of correct DDA references. Finally, the answers on the DDA quiz were scanned as a percentage correct. Table 4.5 shows the results of these analyses of effectiveness.

Again, there were no significant differences between the two versions of the job aid. Users found about a third of the changes noted by the SUNY team, again for first time users. Less than one unnecessary change was made on average by each first-time user. Both groups of users scored well on the knowledge quiz (averaging over 90%).

Usability Rating Scale data was analyzed by comparing the mean ratings for the two versions using a Wilcoxon text. Figure 4.9 shows the rating scales used which were common to both versions of the DDA with "P" and "C" marked on each scale to represent the mean ratings of paper-based and computer-based versions of the DDA.

Table 4.5 Analysis of effectiveness in usability tests

Measure	Score, Paper-based DDA	Score, Computer-based DDA	Probability of Difference
Percentage hits on task	**31.3%**	**39.2%**	**0.155**
Number of false alarms on task	**0.7**	**0.7**	**1.00**
Percentage correct on quiz	**88.9%**	**98.5%**	**0.44%**

Again, there were no significant differences between the two versions. Both versions were rated highly for appropriateness to the task (Q1), easy of finding information (Q2), overall usefulness (Q5), and overall ease of use (Q6). Users were less happy with the writing of the DDA itself and their own understanding of terms mentioned in the DDA. All of the additional evaluation scales used exclusively for the computer-based version scored a mean of 4.0 or above on their 5-point scales.

From the whole evaluation the effectiveness and usability were positive. First-time technical users of the DDA with less than 20 minutes of training-plus-quiz were able to find about a third of all the expert-recommended changes in a typical EO during about an hour's work. After the experience, they rated the design aid highly, although noting that some aspects of DDA wording could be improved. Neither version of the DDA was significantly better or worse than the other, although with only six users in two groups the tests were quite insensitive. In response to this evaluation, all of the text items within the DDA have been reviewed and revised to remove ambiguities and help explain technical terms.

4.7 CONCLUSIONS

To improve the ability of technical writers and engineers to write usable documents, two versions of a Documentation Design Aid were developed. The paper-based version merely lists the rules in a format suited to the user's needs. A computer-based version adds reasons for the rules and examples of their use. Both versions were similarly effective in allowing users to find and make changes in existing task documentation. During the process of developing these job aids, a number of other issues emerged which also impact the process of designing, testing and using technical documentation.

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4.9 APPENDICES

4.9.1 Appendix A - Bibliography

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4.9.2 Appendix B - DDA

1. INFORMATION CONTENT:

1.1 User-centered Design

Checked

- Write with the specific users in mind, e.g. AMTs (mechanics), inspectors. Given information has to be flexible and helpful for both novice and experienced user. ______
- Provide multiple levels of information to cater to the needs of both recently practiced as well as less familiar users. Provide more elaborate information for recently practiced and more concise information for experts performing the same task. ______
- Develop a standard framework for distinguishing between and writing multiple level of information. For example, provide main heading and checklist information for the most experienced user, and supplement this with more detailed information, perhaps in a smaller type, for the less experienced user. ______
- Information provided should be updated and supportive of the user's personal goal to 'read quickly and also understand the information', to ensure that it can be easily understood and used without error. ______
- Write for the appropriate reading level of the user. While AMTs have a high level of reading ability, keep a reading level down to grade levels 6-8 to reduce errors for complex instructions to be read under adverse conditions. ______

1.2 Logical Content

- Use a title for the document which increases the comprehension of the user.
- Determine hierarchical relations among the components of procedure.
- Keep a standard layout for the document as a whole. At the beginning of the document, use the headings of :
  - Purpose
  - Effectivity
  - Equipment
  - Materials

  Follow these by the task instructions and finish with any managerial information and the feedback sheet (if required).
- Determine appropriate and sensible job sequence. Write instructions precisely according to the logical and temporal order in which the individual task has to be carried out.
- If the blocks of task steps are not applicable, allow the user to sign off one block as "N/A" to cover them all.
- Prepare an outline form to show the operations required in step-by-step sequence with special attention directed to key points of the job.
- Use a flow chart to help design the document. Chart the sequence of tasks, particularly the choice points and alternative procedures. Put task step numbers on the flow chart.
- Use reminders of the critical procedures on the form itself instead of using preliminary instruction.
- Revisions, additions, and deletions shall be identified by a vertical black line or code letter "R" along the left margin of the page opposite only that portion of the printed matter that was changed.
- Include the most recent revision date at the start of the document.

1.3 Task Sequencing

- The task information should be ordered/sequenced in the natural order in which the tasks would be carried out by most users.
- Check the sequence to ensure that movement around the aircraft is minimized. Group physically-adjacent tasks close together to reduce user effort
- Each chunk of directive information should not include more than two or three related actions per step to eliminate action slip.
- Break the information used for work instruction into manageable chunks in logical order.
- Divide the information chunks into logical and sensible steps.

1.4 Headings and Levels

- Headings on the same level of organization should be placed and emphasized in a consistent way.
- Number the steps.
- The path among task instructions must be clearly visible .
- Do not use more than three levels of subordination (headings and subheadings) within each major division if it is possible.
- Use minimal number of visual characteristics necessary to differentiate among the headings as each difference implies an additional structural difference.
- Use short paragraphs, headings and sub headings to group and arrange the text.
- Use clear and understandable headings and subheadings .
- Prepare a topic diagram for the content of the document which will be helpful for hierarchical organization.
- You may number paragraphs and sections if necessary .
- Make clear difference among the category responses .
- Determine subdivisions and heading levels of the text in a sensible manner .

1.5 Notes/Warnings

- Insert notes, warnings, and comments into the instructions wherever necessary to ensure safe and accurate performance.
- Use warnings, cautions, and notes to highlight and emphasize important points when necessary.
- Distinguish among directive information, reference information, warnings, cautions, notes, procedures, and methods.
- Use cautions and warnings directly above text to which they relate and vertically in line .
- Use notes after the related text .
- Cautions, warnings, and notes must be on the same page as the text to which they apply .
- There should be a code for identifying the importance of a particular category of information over others, e.g. warnings, cautions, notes, procedures, methods, directive information, references in decreasing order of importance.

2. INFORMATION READABILITY:

2.1. Typographic Layout:

2.1.1. Page Size:

- Use a standard paper size. In the USA this should be 8-1/2" X 11. In the rest of the world use A4.

2.1.2. Page Layout:

- Use a single column layout as this is easier for lower level readers, and does not affect more experienced readers
- For 8-1/2" X 11 paper use a left margin of 1.5 inches and allow at least 1.0 inches for all other margins. The ideal line length is 10-12 words, or about 6"-7."
- Label each page with a subject heading at the top .
- Number each page sequentially placing the numbers at the lower right corner, 0.5 inches above the bottom edge of the page and not extending into the right margin.
- There is no need to end every page at the same point, i.e. the baseline can vary from page to page.

2.1.3. Justification:

- Use left justification, i.e. typing lines up at left edge only. Center and right justification is distracting and can slow reading speed.

2.1.4. Paragraphs and Indentation:

- Use modified block style with two space indentation for subdivisions, as used in this document.
- Label each leading and subheading sequentially 1, 1.1, 1.1.1, etc. as used in this document.
- Within a heading, keep paragraphs below half a page in length, to help the reader's concentration.
- Leave one blank line between paragraphs.

- Do not indent the start of each paragraph.

2.1.5. Spacing:

- Use 1:2 space ratio between sentence spacing and paragraph spacing .

2.1.5.1. Vertical Spacing:

- Use one blank line to separate all paragraphs, and headings .

2.1.5.2. Horizontal Spacing:

- Use one space after commas, colons and semicolons .
- Use two spaces after periods, question marks and exclamation marks .

2.1.6. Typeface:

- Use the typefaces which have a relatively large height , are moderately expanded, solid rather than delicate looking, and have fairly uniform type color such as Times Roman, Century Series, New Gothic, Helvetica in which Times Roman font style is the most common and the least fatiguing to proof readers due to its easy readability.
- Keep the font consistent throughout the document and between documents.

2.1.7. Typesize:

- Use sizes between 9 and 12 point for ease of reading. The best size for most uses is 11 or 12 point.

2.1.8. Emphasis:

- Keep a consistent use of emphasis throughout the document and between documents .
- For a single word use bold (most preferred), underlining, italic or all capitals (least preferred) for emphasis.
- For lengthy passages use bold or underlining for emphasis. Avoid CAPITALS or *italics* as they slow reading and reduce comprehension.
- Use only one or two emphasis techniques within a document to increase comprehension. Bold and underlining are good choices.
- Do not overuse emphasis techniques as it causes confusion and reduces comprehension.

2.1.9. Responses:

- If you are using a check box following the related instruction, do not use large gap between the check box and the instruction.
- Avoid the use of a sign box with " Not Required" or "XXXXX" if the user of the document is not responsible for the instruction accomplishment.
- Use a consistent check box design throughout the document if it is possible .
- Give enough space if you are expecting any answer from the user .

2.1.10. Color:

- Avoid regular use of color in illustrations. Use distinctive shading patterns within black line images instead of color.

2.2 Pagination

- Avoid use of any reference back to previous text .
- Avoid references to other sections of the document as far as possible. Unavoidable cross-references must be precise and unmistakable.
- The page should act as a naturally occurring information module, i.e. it should contain an appropriate number of tasks and avoid carryover of task across pages.
- Each task that begins on a page should also end on that page .
- Minimize the routing; in other words, do not route the user from page to page since it can cause serious defects.

2.3. Letters, Words, Numbers:

2.3.1. Letters and Numbers

- Use lower case letters instead of upper case in the text since lower case letters are much easier to read than upper case letters due to the lower case letters' more distinguishable shapes (ascenders and descenders). Besides, upper case letters occupy more space (40%-45% more than lower case letters do) and reduce the reading speed between 13% and 20%.
- Use mixed-case headings and sub-headings instead of all capitals to improve readability.
- Avoid hyphens which merely indicate word division at the end of line.
- In series of words or statements which present mutually exclusive choices, making the "or" explicit throughout the series enhances comprehension.
- Avoid using Roman numerals since they are not easy to read and cause confusion.
- Use Arabic numbers followed by a period for each item in your list if you should use the numbers. If not, you can use a bullet or dash to get the attention of user.
- Do not enclose the number in parentheses.
- Use a conventional dash-number breakdown : chapter-section-subject-page: 26-09-01-02.

2.3.2 Words

- Avoid using multiple terms for the same object .
- Use precise, unambiguous and common words, with which the user of document is familiar, throughout the document for consistency.
- Do not use many prepositions, they cause user to read slowly.

2.3.3. Abbreviations

- Use only approved acronyms and proper nouns.
- Avoid abbreviations. If you have to use abbreviations, then
  - Use them consistently,
  - Use first few letters to remind the word.
- Provide a glossary if the users need. In particular, if there is an unavoidable inconsistency for abbreviations, then use glossary of interchangeable designations.

2.4. Writing Well:

2.4.1 General Considerations on Writing

- Try to achieve a balance between brevity, elaboration and redundancy of information.
- Complement verbal material by appropriate pictorial representation.
- Adapt the format of instruction to the characteristics of the respective task.
- Write clear, simple, precise, and self-explanatory instructions.
- Minimize writing requirement from the users of documents.
- Summarize the main ideas of lengthy prose passages in a section before the text since it aids in learning the context.
- Use adequate information in the instruction steps.
- The text should be written in a consistent and standardized syntax.
- Text shall be as brief and concise as practicable.
- Use a logical structure sentences and paragraphs since they are easier to understand and remember;

  Logically: - place general before specific provisions,
  - place important before lesser provisions,
  - place frequent provisions first,
  - place permanent before temporary provisions.

2.4.2. Sentences

- Use Simplified English as much as possible .
- Use short sentences instead of long ones since short sentences are easier to read and understand.

- Use definite and affirmative sentences in active tense instead of using negative forms and passive tenses since active voice increases comprehension.
- Use sentences with personal pronouns since they increase comprehension and reader's motivation.
- Sentences with many subordinate clauses are difficult to comprehend.
- Sentences with action verbs are easier to read and understand than sentences with nominalization.
- Do not use the sentences with a long noun string, since they are hard to understand.
- Do not use the sentences with whiz deletions since they create ambiguity and are hard to read.
- Use third person for definitions as follows:

  " The torsion link assembly transmits torsional loads from the axle to the shock strut."
- Use second person imperative only for operational procedures as follows :

  " Check the oil level."
- Ideas expressed in positive terms are easier to understand.
- State directly what you want to say without excess or unnecessary words since the sentences with unnecessary words are harder to understand and take longer to read.

2.4.3 Lists and Tables

- Data and information presented in the tables facilitate understanding and comparison.
- In lists and tables, do not leave blanks within a line greater than half an inch or five spaces.
- Group the lines in lists and tables according to content.
- Do not group more than five lines together.
- Separate the groups in the list and table by spacing.
- Write the list of items in parallel construction since that way is easier to read and remember.
- List a series of items, conditions, etc. rather than displaying them in a series separated by commas.
- Avoid using compound questions and statements.
- Minimize the logically related question as much as possible.
- Construct the questions in a way which requires minimum memory use from the user of the document.

2.5 Graphic Information:

- Place the visual item in the text of a document, near the discussion to which it relates. If it is not possible, place the visual item in an appendix, label and refer it.
- Use a clear title with a figure or a table number on the line directly below all illustrations.
- Use the same title for illustrations as corresponding text subject title .
- Use either a horizontal-landscape format with the top of the illustration at the binding edge or vertical layout to present graphic information for ease of reading and cross reference consistently.
- Adequate text must be supplied to support illustration not vice versa.
- Draw the illustration in a size and line weight such that they can be used without any rework for the production of projectables.
- Develop uncluttered illustration with limited information/learning points, and presented in a self-explanatory way.
- Use illustrations as the primary source of the information transfer.
- Present all spatial information in graphical format instead of in textual format.
- Label each table or figure with Arabic numeral such as Table 1, Figure 1.
- Use simple line drawings which are superior in most cases.
- Use a consistent format for figure layout and numbering.
- Use illustrations whenever they will simplify, shorten, or make the text easier to understand.
- Do not use complicated reference numbers for figures, e.g. T07-40423-001.
- Avoid use of perspective part drawings as figures.
- The figure views should be as the user sees it.
- Use standard and correct technical drawing terminology, e.g. avoid use of terms 'section' and 'view' interchangeably.

- Reference all tables and figures in the text by the numbers.
- Use bar charts to make accurate comparison of numerical data whenever you can.
- Line charts (or graphs) help to understand trends and allow accurate comparison between two or more numerical values.

2.6. Printing and Copying Quality:

- Check the toner box regularly to have consistent copy quality.
- Make sure that no major image degradation occur with reproductions of originals.
- Use the paper which has a reflectance of at least 70%.
- Use low visual acuity and large typesize if user is going to use the document under low illumination level.
- Readers prefers matt paper to medium or glossy paper.
- High opacity paper is preferable.
- Use black ink on white paper since it is more effective than white ink on black paper.
- Develop and implement standards for changing printer ribbons, toner boxes etc. to ensure a consistent print quality at all times.

3. OTHER ORGANIZATIONAL ISSUES:

- Allow the prospective users of workcards to participate in the design of the document.
- Check every individual instruction by testing it in the field situation.
- If your document is going to include multiple copies, color can be a useful processing aid.
- Make sure that user is aware of how to correct an erroneous entry.
- If the feedback sheet is to be faxed, provide unambiguous instructions which will work for all users.

Chapter 5
A PROACTIVE ERROR REPORTING SYSTEM

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5.1 A PROACTIVE APPROACH TO ERRORS

Considerable effort has been expended by airline personnel and human factors researchers in trying to identify errors in aviation maintenance. The aviation maintenance environment is a large and complex socio-technical system with many opportunities for error and well established safety systems to prevent error propagation. Inspectors and mechanics must utilize documentation, tools, and other personnel to detect, document, and repair faults within the constraints imposed by both the physical environment and the organizational environment. Since it is the inspectors and mechanics themselves who are ultimately responsible for identifying necessary faults needing repair, and for judging whether repairs are adequate, many errors can be identified at some level as a human error.[1] Thus, high importance has been placed on identifying human errors in the maintenance system, and for reducing the possibility for future errors.

The aviation industry and the FAA have identified reducing human error as a major contributor to improving the safety and reliability of aviation. The FAA Office of Aviation Medicine (FAA/AAM) has been conducting research throughout the 1990's on Human Factors in Airline Maintenance. Researchers, ourselves included, have been examining all facets of the airline maintenance environment in an effort to improve performance, reduce errors, and match the abilities of the mechanics with their work, by giving them better tools with which to perform their jobs.

During the last six years, various maintenance and inspection processes have been analyzed through observations, task analyses, and other research efforts to identify potential errors in the system. Audits have been developed for both inspection and maintenance tasks to help identify problems in the system which may result in errors.[2] Mechanics have been surveyed, and human factors task forces formed, to help identify more subtle socio-technical problems existing in the maintenance system. In addition, analysis of historical error data has allowed hazard patterns of typical errors to be developed, and latent failures in the maintenance system to be identified. The challenge is to combine these disparate elements into coherent error management systems.

As a starting point for this integration, in 1995, our team examined many errors that are committed in the maintenance environment including: ground damage incidents, paperwork errors, on-the-job injuries (OJIs), rework situations, late finds, etc. For each of these error outcomes, we were able to use a small number of repeating patterns of behavior to classify the errors. Where the data would support it, we used event trees to relate these patterns to underlying human (and other) factors, i.e. root causes. We concluded that there is a relatively small set of common root causes which can lead to different error outcomes in the maintenance environment. Thus, by eliminating (or reducing) these common root causes, it will be possible to prevent mechanics from committing a large number of errors. In order to eliminate the underlying causes of problems, it is necessary to make changes in the maintenance system. The "blame and train" approach is often not sufficient, as it affects only one or two individuals in the system rather than the system itself.

There has also been significant interest in improving the manner in which airline maintenance personnel record errors and track their incidence by location and over time. The Maintenance Error Decision Aid (MEDA), developed by Boeing for use by the airlines, is one tool that has been introduced to help airlines track low-level errors in the maintenance environment. MEDA was initially intended to allow airlines to share error data with the rest of the industry, which would allow airlines to learn from each other. This feature was not widely accepted by the industry, as few maintenance departments were willing to release their error information publicly. However, MEDA does provide maintenance personnel with an additional tool for tracking errors.

In fact, considerable time, effort, and money is spent in the identification and tracking of some errors. For example, there are clerks whose entire job is the checking of paperwork for errors, and programs have been set up within airlines to investigate errors when they occur. Other airlines have invested heavily in the purchase of commercially available error reporting systems.

Our previous research has indicated that airlines typically have many error reporting systems in use simultaneously. Injuries, ground damage, paperwork errors, etc. are all recorded in separate error reporting systems. Some errors, such as rework situations, may not even be explicitly captured in any of the existing error reporting systems. However, maintaining separate reporting systems based on error outcomes is not efficient in monitoring error root causes, since many error outcomes result from a similar set of root causes. For example, if a mechanic drops a wrench on his foot it is recorded as an OJI, but if the wrench is dropped on the aircraft, it is recorded as a ground damage incident. Maintaining different reporting systems requires significantly more effort to identify, and ultimately address, common root causes. In particular, the potential savings associated with an intervention may be considerably underestimated if only a single error outcome is counted.

Another result of our previous research is that the same types of errors occur repeatedly in the airline maintenance environment. These errors are often predictable, and are not unexpected by either the mechanics or management. Maintenance personnel are often familiar with these errors, and management often have tools available to help them identify error-prone situations. However, similar errors continue to occur in the airline maintenance system. This leads to the conclusion that the difficulty is less how to recognize the human factors problems (actual and potential errors), than how to move from recognition and analyses of the problem to usable solutions. Help is needed in guiding maintenance personnel in making changes in the system before errors can repeat.

A Proactive Error Reduction System (PERS) has been developed to meet this need of airline maintenance personnel. PERS can be used to foresee, and thus prevent, typical errors. The system is essentially a database of solutions, which have been shown to successfully address problems in the airline maintenance system. Users can search the database to find potential solutions, either to errors that have occurred, or to known potential error-causing situations.

5.1.1 Goals of PERS

Three distinct functions were identified to ensure PERS is an effective error management tool: an error reporting/tracking function, a means of predicting future errors, and a way to find alternate solutions to error problems. First, PERS must include an error reporting system which, like current reporting systems, allows errors to be investigated and recorded. The error reporting system function should allow many error outcomes to be recorded in one unified system, so that common root causes can be identified and tracked. The system should guide the error investigation to ensure the details of the error, including root causes, are being identified and captured. Interfaces to existing error reporting systems (e.g., MEDA) may facilitate acceptance of PERS by airline maintenance departments already using such systems.

Second, PERS should allow users to import data from other sources, which are not triggered by known errors. Thus, other proactive investigation tools (e.g., Audits, MESH, etc.) can be used to identify potential error-causing situations, and PERS can be used to help prevent these errors from actually occurring.

Finally, PERS is a way of linking a database of maintenance errors with a database of known solutions. It will contain alternative solutions that can be implemented to help reduce the occurrence of these errors. Users will be able to search this database directly, to find possible solutions for problems that are known to exist in the maintenance environment, regardless of whether an error has actually occurred. Within the solution search, information regarding cost, typical implementation time, and success stories should be provided to the user, to allow more educated choices to be made when choosing how to address problems.

These second and third characteristics of proactivity and solution-orientation are what differentiate PERS from existing error investigation systems. Figure 5.1 shows the conceptual structure of PERS, and its central role in an error management system. The multiple entry points are shown at the top, with proactive ones on the left and reactive (event-driven) ones on the right. From either potential or known problems, a set of contributing factors are derived and used to find actual or potential Hazard Patterns. These Hazard Patterns and contributing factors are used with the solution database to find appropriate solutions. The user assesses potential solutions against selection criteria to find a subset of usable solutions, which then become part of an ongoing error control and management system.

5.2 PERS DEVELOPMENT

The three functions of PERS (Section 5.1.1) have been considered as three distinct modules in the PERS program, and their development will be presented in turn, although the core of the PERS program ensures that these modules can interact correctly. The interface to other data sources has not been considered in this phase of the program, except in the recognition that 'gateways' must be left open for such data transfer to occur. For example, PERS must be able to recognize output from proactive tools such as audits, to provide solutions that can prevent errors from occurring. PERS must also be capable of importing data from other error reporting systems, to allow solutions to be found for errors that have already occurred and that have been recorded in an alternate form.

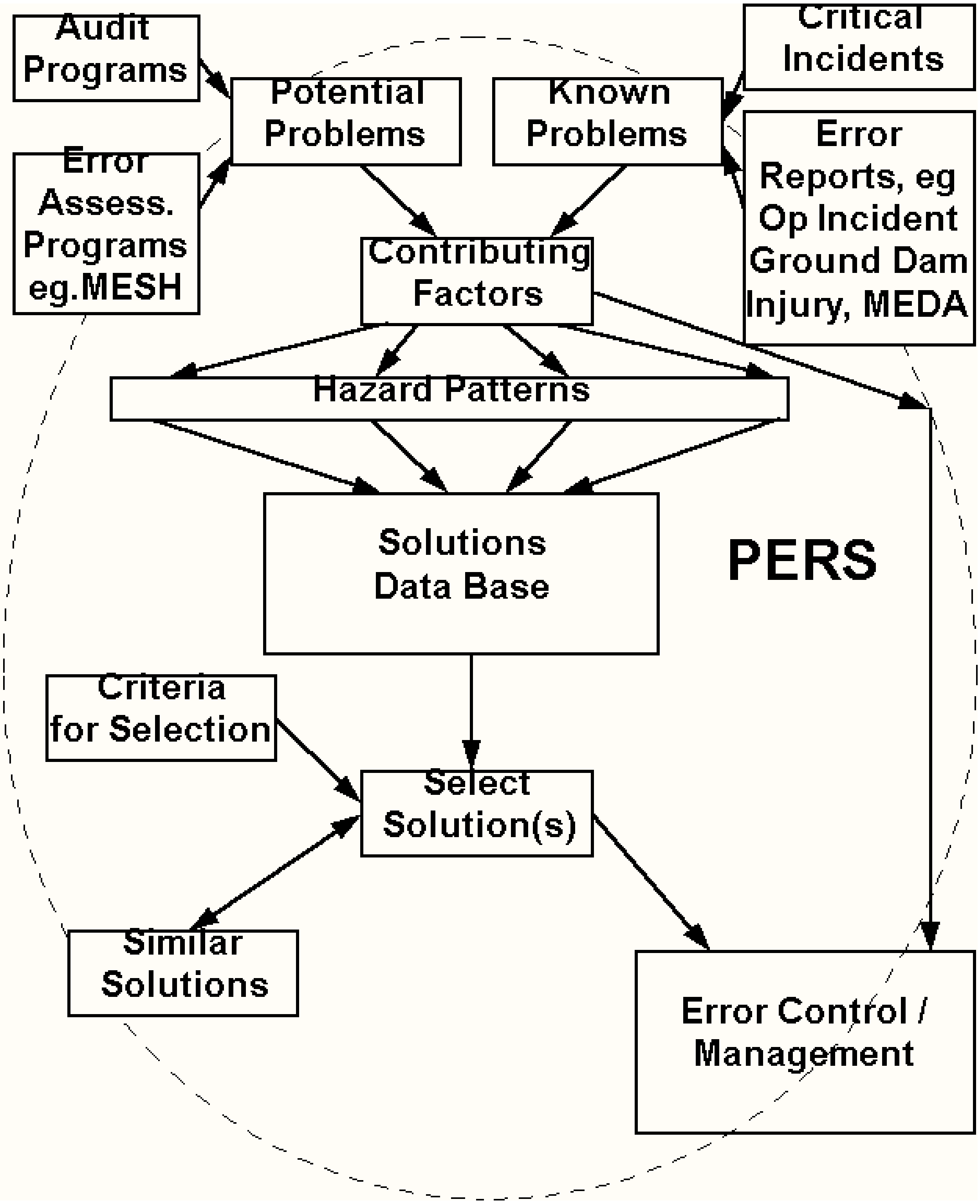

Figure 5.1 Conceptual Structure of PERS

5.2.1 Error Reporting System

The development of a unified error reporting system is not a trivial problem. It is necessary to balance the need for extensive information about an error, with practical usefulness in an airline maintenance environment. A system must contain enough narrative information to allow root causes to be identified and classified, but should not necessarily require a two day investigation of each error that occurs. It is important, however, to remember that the information gained from an error reporting system reflects the effort that was expended in recording the information. More time and energy spent capturing and recording an error usually results in a richer error report, containing more useful information and leading more obviously to root causes and hence to solutions.

In developing an error reporting system, it is necessary to consider who will be completing the error investigations: maintenance personnel, or human factors professionals, as the tools for these users may look completely different. For example, human factors professionals may be better able to answer general questions based on a human factors model of causal factors (Tools/Operators/Machines/Environment [TOME], Software/ Hardware/ Environment/Liveware [SHEL]), e.g., "Describe how the environmental factors contributed to the error." On the other hand, maintenance personnel may be better suited by questions more tailored to the actual error, e.g., "Was it raining while the task was being performed, and if so, how did the rain affect task performance?" Since most airlines do not have sufficient human factors personnel available to investigate all errors that occur, the second approach may be better suited for the airline maintenance environment.

It is also important to consider the types of responses that will be required of the error investigators. Answers can range from selecting a suitable response from a predetermined list (checklist approach), to requiring investigators to write long narratives describing the situation. Our analysis of existing error databases has indicted that narrative responses usually provide more, and more usable, information than checklist responses. For example, the checklist approach to MEDA has restricted the amount of information recorded about an incident to a point where it is even difficult to reconstruct the chain of events leading to the error. However, narrative responses require personnel to write lengthy descriptions, and writing is not a skill most airline personnel enjoy using. In addition, narrative responses take longer for the investigator to complete, and the data is more difficult to utilize. Narrative responses must be carefully analyzed, and the root causes extracted from the narrative, before the data is in a useful form.

A Unified Error Reporting System was developed as part of our previous research. This system, in paper form, leads users through a narrative based investigation system tailored for particular error outcomes. The questions for each error outcome have been developed based on analysis of historical error data and on the common root causes identified for each type of error. This analysis helps to focus an error investigation on the factors that have been shown to typically result in that type of error. A computerized version of this system will be developed for use in the PERS system.

5.2.2 Solution Database Development

In order to make PERS a proactive error reporting system, users should be provided with information on how to prevent potential errors from occurring. The objective was to gather a large database of errors from the airline maintenance environment, along with solutions that have been used by airlines to address these errors. This would allow users to learn from the mistakes of others and to improve their system before predictable errors can occur.

Unfortunately, it has been a very difficult task to collect this solution information. We have found that few airlines have maintained detailed records of solutions that have been implemented, and even fewer have performed follow-up analyses of these solutions to judge how successful they have been at preventing future errors. Some airlines have implemented solution generation as part of their current error reporting systems, by requiring investigators to recommend solutions at the end of an error investigation. For example, investigators of ground damage incidents are required to make a few recommendations as to how to prevent future incidents. However, these recommendations tend to take the "blame and train" approach, in which the particular maintenance personnel involved in the incident are reprimanded, and additional training is suggested for all personnel. Such a strategy has proven singularly ineffective in reducing systemic errors.

In addition, airlines have implemented wide-scale programs intended to address human factors problems within the organization. Maintenance Resource Management (MRM) programs, Task Analytic Training (TAT) sessions, and Total Quality Management (TQM) techniques (such as teams or project ownership) are being used. Their successes are being documented as global solutions to problems, that are known to exist in airline maintenance systems. Solutions to specific problems, however, are not as well documented.

It is important that the solutions in the PERS database reflect more than obvious solutions to known problems. For example, including a solution to "improve communication" will not be useful to address a problem identified to be "lack of communication between leads on consecutive shifts." A better approach is to include specific solutions that have been shown to work in other airlines, or even in other industries. An example of a more specific solution to the lack of communication problem is to "overlap shift start and end times, and require the two leads to walk around each aircraft to ensure a complete turnover of current work information." We are most interested in airline specific solutions, since airline personnel trust this information more than solutions from other industries. However, other solutions from other industries will be included where applicable to the aircraft maintenance domain.

The collection of solutions to populate the database is ongoing, and it is envisioned that this will in fact be a continuous process. We are still working with our airline contacts to obtain information about solutions that have been implemented and as much detail about these solutions as is available. In addition, we are investigating best practices within the airline industry, to allow recommendations to be made for potentially error-causing situations that have been identified according to the human factors literature. So far, all of the documented solutions from the FAA/AAM Human Factors in

Aviation Maintenance conferences have been collected and included.

5.3 PERS STRUCTURE

An overall structure for the PERS software has been developed, leaving "gateways" to the modules of the program which will be developed in the future. Most of the effort concentrated on the solution search aspect of the program, with emphasis on ground damage incidents. Ground damage was chosen for this initial phase since detailed analysis of these incidents has been previously conducted.

The solution search module of PERS has three main components. First, the event leading to an actual error, or to a potential for error must be described. Then, the latent and active failures contributing to the error are identified, and finally possible solutions are suggested to address these failures. The initial screen (Figure 5.2) allows the user to select the appropriate module.

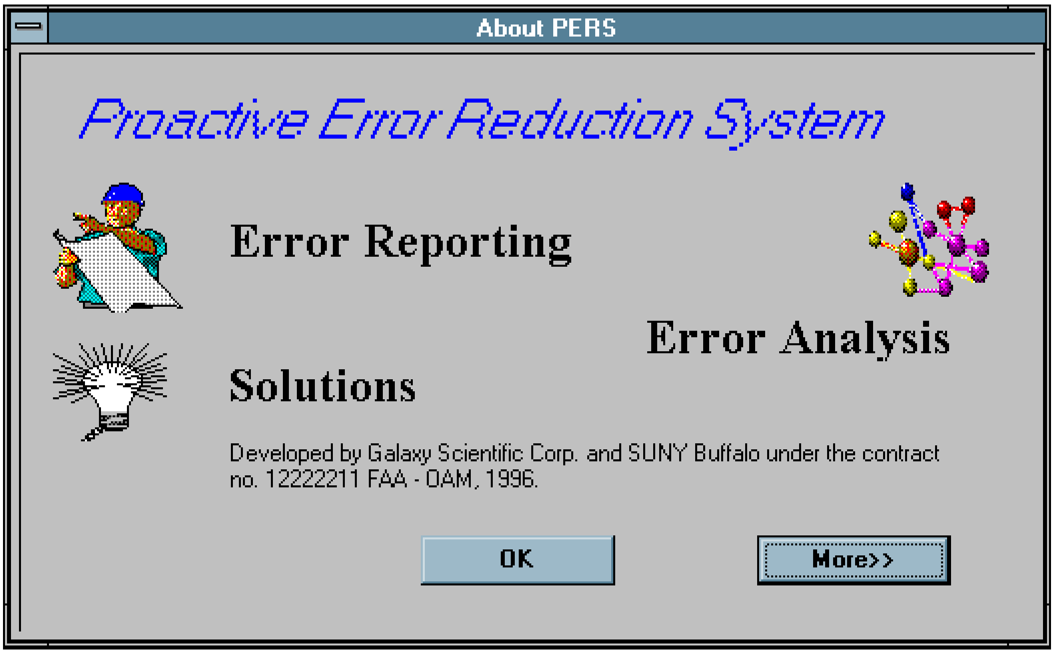

Figure 5.2 Modules of PERS

5.3.1 Error Description and Failure Identification

Ground damage includes damage to aircraft which is caused by airline personnel. It includes damage that is preventable. Damage caused by hail, bird strikes, part failures, and even foreign object damage (FOD) is not recorded as ground damage in the database we analyzed in 1995. This database covered 130 ground damage incidents recorded by a technical operations department of a major airline over a three and a half year period. (This restricted coverage, e.g., not covering FOD, is one of the problems PERS was designed to overcome). It was determined that there were only twelve distinct patterns of error outcomes that covered all of these incidents, as shown in Table 5.1, each of which was considered to be a Hazard Pattern. For example, the center of gravity of the aircraft may change unexpectedly, resulting in Hazard Pattern 1.2.1

Next, each of the incidents were analyzed to determine the specific latent failures that contributed to the incident, and scenarios were developed for each hazard pattern which illustrate the common factors between all of the incidents. From this detailed analysis, typical event trees leading to the twelve hazard patterns were developed, and the common latent and active failures leading to these error outcomes were identified (Figure 5.3). These event trees were used as a framework to guide users to potential solutions for errors often resulting in ground damage incidents. The user is able to navigate through these trees as the event is described, ending at a list of the common failures (root causes) that often contribute to the event.

This approach eliminates the need to carefully investigate each ground damage incident, since the detailed analysis has already been performed, and allows the user to move quickly to possible solutions. Figure 5.4 shows the point in the PERS software where the user can choose the form of analysis. Similar detailed analysis of other incident types must be conducted in the next phase of this project.

Table 5.1 Ground Damage Incident Hazard Patterns

Hazard Pattern	Number of Incidents			% of Total
1. Aircraft is Parked at the Hangar/Gate/Tarmac	81			62.3
1.1 Equipment Strikes Aircraft		51		
1.1.1 Tools/Materials Contact Aircraft			4	
1.1.2 Workstand Contacts Aircraft			23	
1.1.3 Ground Equipment is Driven into Aircraft			13	
1.1.4 Unmanned Equipment Rolls into Aircraft			6	
1.1.5 Hangar Doors Closed Onto Aircraft			5	
1.2 Aircraft (or Aircraft Part) Moves to Contact Object		30		
1.2.1 Position of Aircraft Components Changes			15	
1.2.2 Center of Gravity Shifts			9	
1.2.3 Aircraft Rolls Forward/Backward			6	
2. Aircraft is Being Towed	49			37.7
2.1 Towing Vehicle Strikes Aircraft		5		
2.2 Aircraft is Not Properly Configured for Towing		2		
2.3 Aircraft Contacts Fixed Object/Equipment		42		
2.3.1 Aircraft Contacts Fixed Object/Equipment			13	
2.3.2 Aircraft Contacts Moveable Object/Equipment			29	
Totals	130	130	130	100%

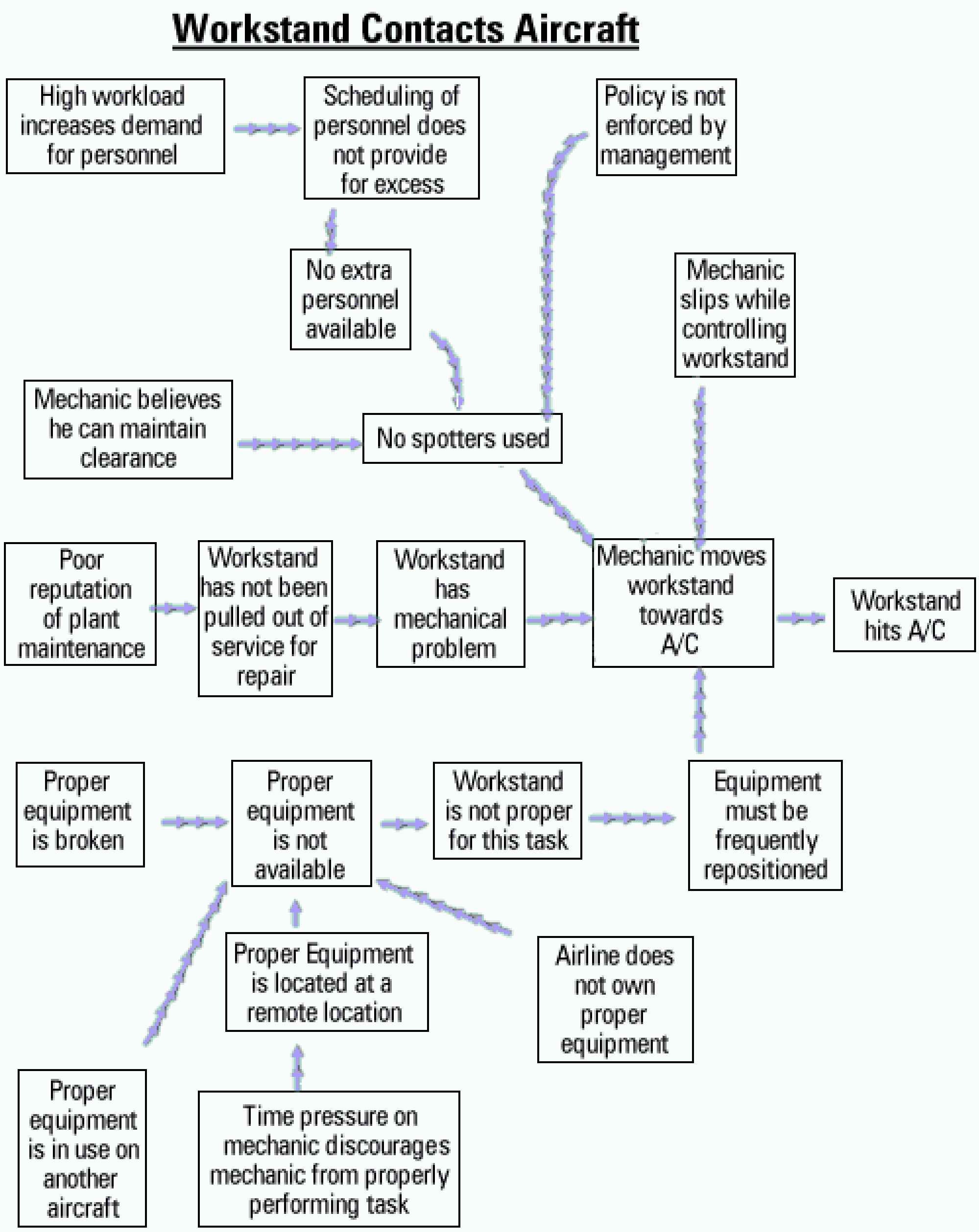

Figure 5.3 Example of Hazard Pattern Event Tree

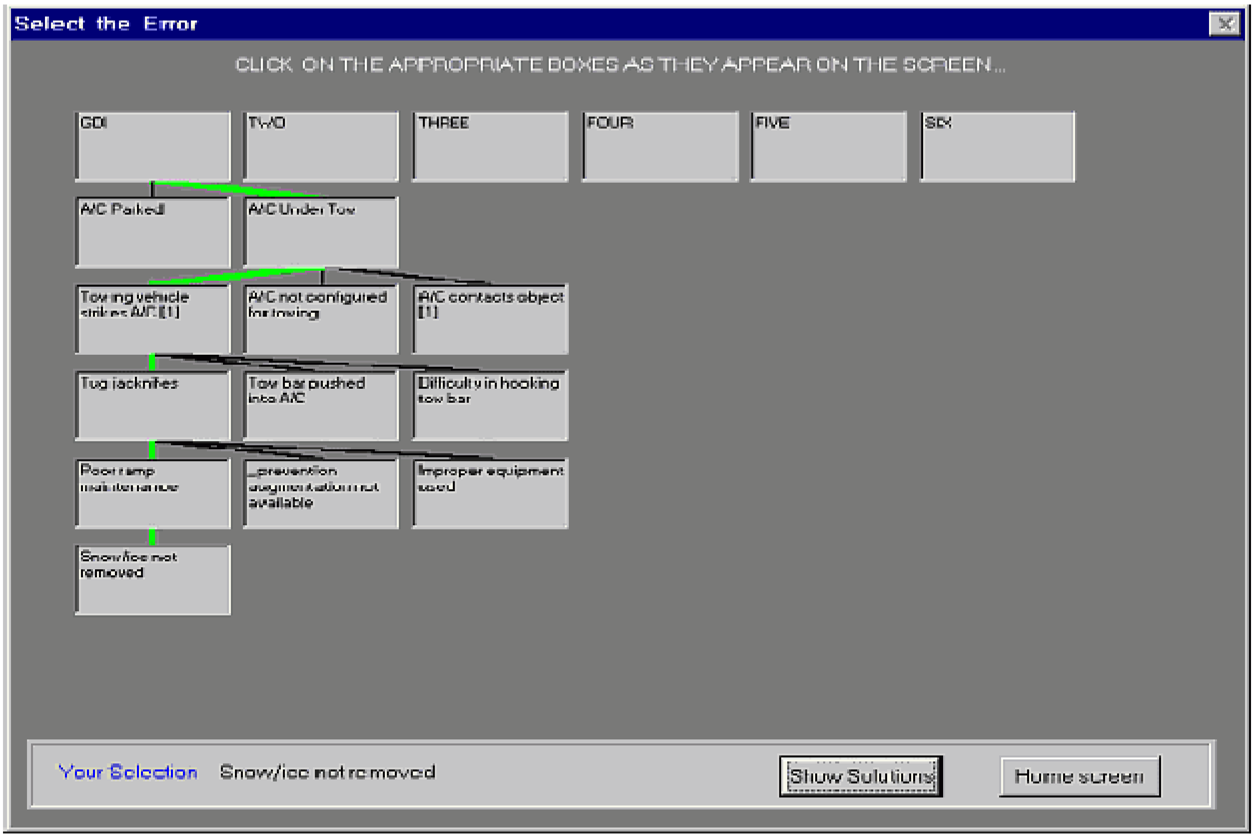

Figure 5.4 GDI Event Description Screen

5.3.2 Solution Search

Once an event has been described and the root causes identified, the user is able to examine possible solutions to each root cause. More detailed information about each solution, including cost, time to implement, and success stories will also be presented, when this information is available. This additional information will allow users to make educated decisions on how to address problems within their facility.

The solutions are indexed within PERS according to causal trees that have been developed. These causal trees describe latent and active failures that may exist, and are independent of errors that have occurred. The causal trees have been developed based on a combination of error classification schemes. The contributing factors from MEDA, performance shaping factors from human reliability analysis in the nuclear industry,3 causal error taxonomies from safety literature,4,5,6 and latent failures identified in previous research7 were reviewed, and some information from each was combined to develop causal trees. The causal trees are a comprehensive classification of all factors that may contribute to an error. Five different causal trees were developed, addressing issues of: Management/Supervision, Communication, Equipment / Tools / Parts, Environment, and Knowledge/Skills/Training. Figure 5.5 illustrates one of the causal trees developed for PERS.

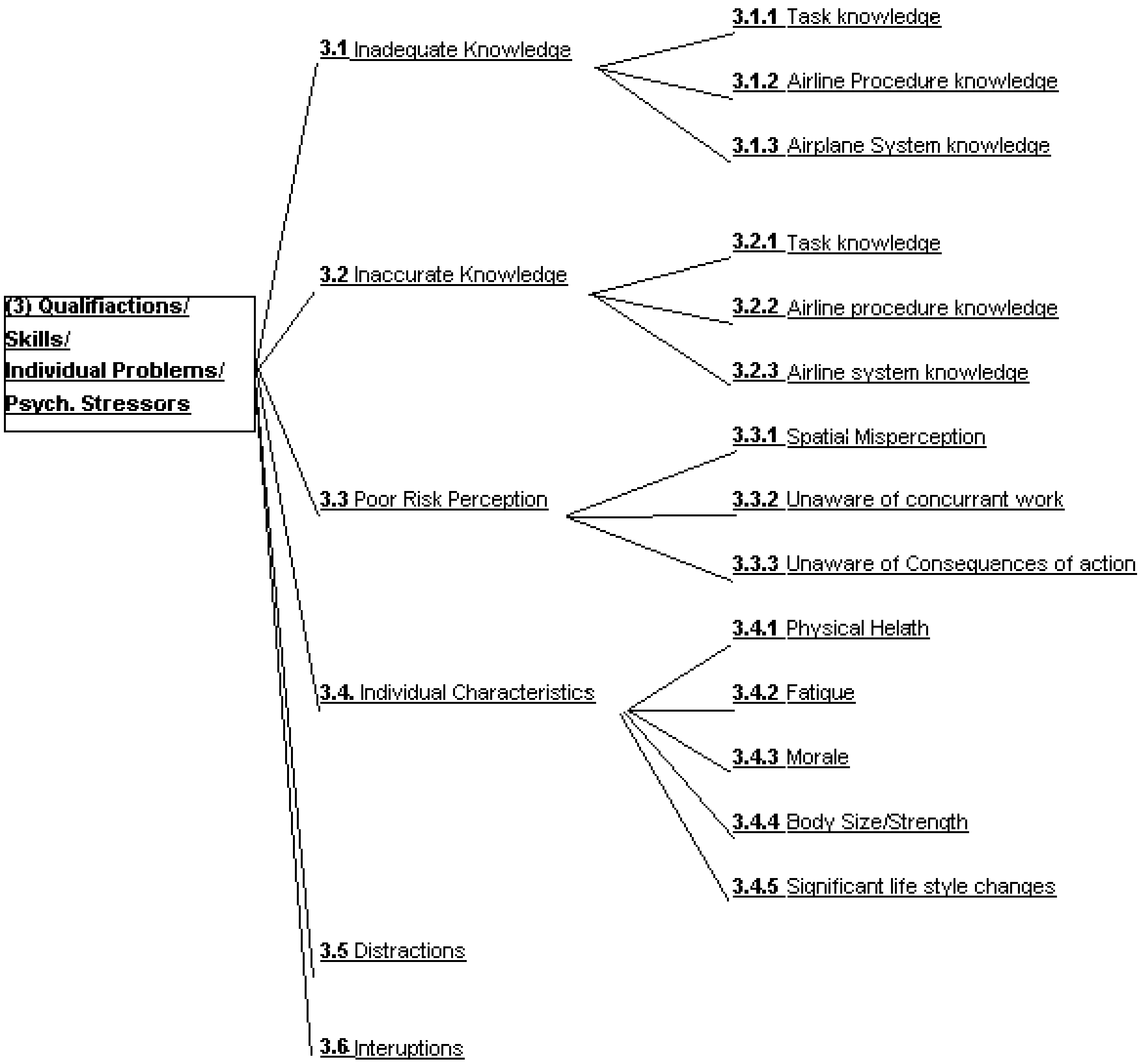

Figure 5.5 Example of a Causal Tree

Each of these causal trees has been embedded in the PERS software, and solutions are tagged to address particular points on these trees. Figure 5.6 shows a typical solution search, with possible solutions identified, in this case derived from prior ground damage incidents (GDI) investigations. More information will then be provided about each of these potential solutions.

In many cases, there may not be solutions that exist for all levels on the causal trees. In this case, the software should allow the user to examine solutions associated with the next higher level on the tree. Thus, users should be able to navigate the causal trees while examining solutions.

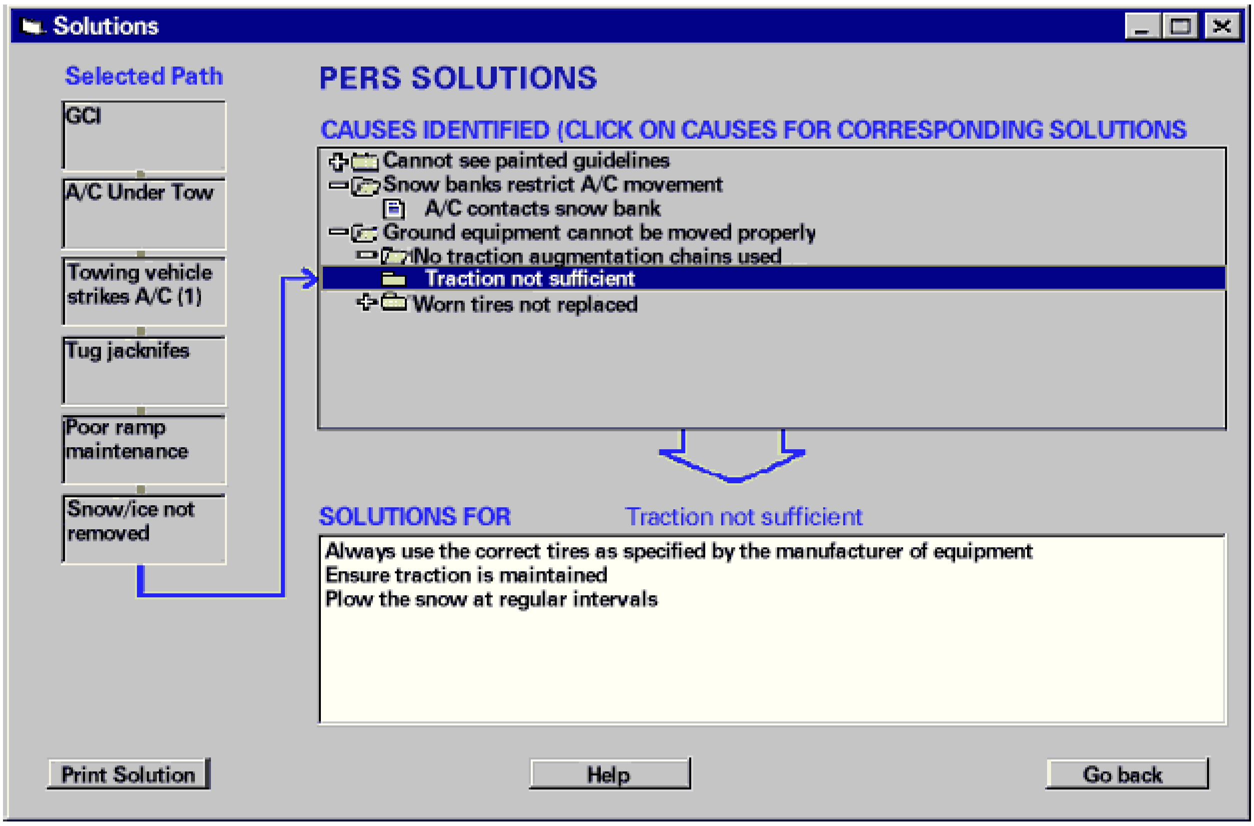

Figure 5.6 Solution Search Screen

5.4 LESSONS LEARNED FROM PERS

At the end of the first year of this two year project, a working prototype has been developed. This showed, on the basis of only one class of error outcomes, that such a system was feasible, in that the logic system could lead to multiple usable interventions based on the active and latent failures encountered. The prototype needs to be further developed in five ways to produce a comprehensive system:

1. The additional error classes need to be included.

2. The proactive aspects, based on audit data, need to be developed and programmed.

3. Links to existing error recording systems need to be programmed.

4. Support aspects, such as on-line help screens and a user's manual, need to be produced.

5. Many more evaluated solutions need to be added to the data base.

Some of those developments are possible immediately. However, two -- additional error classes and more evaluated solutions (Nos. 1 and 5 respectively) -- are not currently possible. Hence, this two year project has been suspended at the end of the first year for two specific reasons:

1. There are insufficient evaluated solutions documented in the industry at present. Despite contacts with the major airlines, the only specific solutions available have been in the published literature, e.g., from previous conferences. In the PERS prototype, these have been supplemented by higher-level solutions from professional good practice, e.g., from the *Human Factors Guide*. Even within GDIs, the solutions are few enough that they do not require an elaborate procedure such as PERS to bring them to the notice of users.

2. For areas other than GDIs, current data bases do not have the depth to support the active failure/latent failure search methodology used in PERS. For PERS to become a universal system, we would have to go back to "long checklist" approach used by current commercial error recording systems as there is too little data to make a reliable transition to our intelligent tree search.

5.5 FUTURE PLANS

Thus, the current status of PERS is that the project is on hold until the data becomes available to fully exploit its structure. If it is reactivated, the other items on the list in Section 5.4 will need to be addressed. Specifically, the "hooks" left to other error types (operational errors, paperwork errors, injuries, etc.) will need to be programmed. In addition the current audit systems such as ERNAP will need to be strengthened to include higher level indicators of human error potential and subsequently coded into PERS. Finally, interfaces to other error recording systems such as TEAM or AMMS will need to be explicitly coded.

At this time, no usability testing was performed on the PERS prototype. Because PERS only covered one area (GDIs), and had so few potential solutions available, it was not considered appropriate to run formal usability trials with industry personnel on the prototype. If PERS is reactivated and developed further, the usability trials can be completed meaningfully.

In summary, PERS as currently developed demonstrates the feasibility of a next generation of error management systems. As current systems develop richer data bases of errors, and as these in turn drive implementation of human factors solutions, the data necessary to resume development of PERS, or a similar system, will exist. Development of PERS to its current level has made the need for such data explicit, and provided the logical framework needed to support a future generation of error management systems.

5.6 REFERENCES

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Chapter 6
ROLE OF COMPUTERS IN TEAM TRAINING: THE AIRCRAFT MAINTENANCE ENVIRONMENT EXAMPLE

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6.1 INTRODUCTION

In order for the Federal Aviation Administration (FAA) to provide the public with a continuing safe, reliable air transportation system, it is important to have a sound aircraft maintenance system.[1] The maintenance system is a complex one with many interrelated human and machine components. The linchpin of this system, however, is the human. Recognizing this, the FAA (under the auspices of the National Plan for Aviation Human Factors) has pursued human factors research.[1,2] In the maintenance arena this research has focused on the aircraft maintenance technician (AMT).[3,4,5] Since it is difficult to eliminate errors altogether, continuing emphasis must be placed on developing interventions to make the maintenance procedures more reliable and/or more error tolerant. In response to this need, this research looked at the role of team training and specifically that of advanced technology for team training in enhancing team performance.

6.2 BACKGROUND

Task analyses of aircraft inspection and maintenance activities have revealed the aircraft inspection and maintenance system to be complex -- requiring above average coordination, communication and cooperation between inspectors, maintenance personnel, supervisors and various other subsystems (planning, stores, and shop) to be effective and efficient.[1,2,6,7] A large portion of work is accomplished through teamwork. The challenge is to work autonomously but still be a part of the team. In a typical maintenance environment, the inspector first looks for defects and reports them. The maintenance personnel then repair the reported defects and work with the original inspector or the buy-back inspector to ensure that the job meets predefined standards. During the entire process, the inspectors and maintenance technicians work with their colleagues from the same shift and the next shift as well as personnel from planning, stores, etc., as part of a larger team to ensure that the task gets completed.[1] Thus, in a typical maintenance environment, the technician has to learn to be a team member, communicating and coordinating the activities with other technicians and inspectors. Although the advantages of teamwork are widely recognized in the airline industry, the work culture assigns responsibility for faulty work to individual AMTs rather than to the teams on which they work.[8] The reasons for this could be the individual licensing process and personal liability, both of which often result in AMTs and their supervisors being less willing to share their knowledge and work across shifts with less experienced or less skilled colleagues. The problem is further compounded since the more experienced inspectors and mechanics are retiring and being replaced by a much younger and less experienced workforce. Not only do the new AMTs lack knowledge or skills of the far more experienced AMTs they are replacing, but also they are not trained to work as a team member.

The earlier problem of the development of individual AMT skills has been continually addressed by FAA. For example, FAR Part 66 (new AMTs certification requirements, not officially established in NPRM stage) specifically addresses the significant technological advancements that have taken place in the aviation industry and the advancements in training and instructional methods that have arisen in the past decade. The FAA, through the Office of Aviation Medicine, has also funded efforts for the development of advanced training tools to train the AMTs of the future.[1,2,9] These prototype training systems (e.g., Boeing 767 Environmental Control System [ECS] tutor and multimedia System for Training Aviation Regulations - STAR) will be available to the A&P schools. It is anticipated that the application of these training technologies on a large scale will help reduce the gap between current AMT skills and those needed for the maintenance of advanced systems.

However, the AMTs joining today's workforce are lacking in team skills. The Aircraft Maintenance Technology Schools (AMTS) provide the necessary technical skills for students to receive both their airframe and power plant certificates (A&P License). The curriculum for AMTS is specified in the Code of Federal Regulations, and presently does not address any instruction on teamwork skills. In fact, the current technical school environment encourages students to compete, and as a result, the AMTs are often ill-prepared for cooperative work. To prepare student AMTs for the workplace, new ways have to be found to build students' technological, interpersonal and socio-technical competence by incorporating team training and communication skills into their curriculum. Furthermore, the importance of teams has also been emphasized in the National Plan for Aviation in Human Factors where both the aircraft industry and government groups agree that additional research needs to be conducted to evaluate teamwork in the aircraft maintenance/inspection environment. 1,2,10 Recent work has examined the effects of team training when applied to students at an Aircraft Maintenance Technology School. Using a previously designed framework for the study of team training in the aircraft maintenance environment, Gramopadhye et al. found a positive correlation between team skills training and the improvement of team performance and overall task performance in an aircraft maintenance situation.11 In addition, the study concluded that student AMTs need to be provided with team skills instruction to prepare them for the teamwork tasks found in the aircraft maintenance environment. However, the study did not address issues related to the appropriateness of the training delivery system. The question that begs to be answered is: What is the best method to present team skills training?

With computer-based technology becoming cheaper, the future will bring an increased application of advanced technology to training. Over the past decade, instructional technologists have provided numerous technology-based training devices with the promise of improved efficiency and effectiveness. Examples of such technology include computer simulation, interactive video discs and other derivatives of computer based application,12 several of which have been employed for diagnostic maintenance training.4,12,13 Furthermore, multimedia has assisted in teaching difficult and complex skills.14 Layton stated that the domain of aircraft maintenance is rapidly becoming the focus of computer-based training (CBT) aids.15 With the use of desktop computers with multimedia packages, new maintenance job aids have been developed to teach technical skills to maintenance technicians. AMTs may learn a variety of skills from CBT that range from scheduling preventive maintenance to applying expert systems for fault diagnosis and repair. Lufthansa Airlines believes so strongly in CBT that they have instituted CBT with video overlays to update the technical skills of their maintenance technicians.16 Andrew et al., also describes various multimedia technologies that have been effective in simulating combat situations for team training in the military.17 Because of the advantages offered, computer-based training may have a role to play in team training in the aircraft maintenance environment. It is important, therefore, to examine the effectiveness and applicability of computer-based multimedia team training for aircraft maintenance technicians. To date, however, no one has examined the role of the advanced technology, specifically computer-based multimedia presentation, for team skills training for aircraft maintenance technicians. The express purpose of this research was to address this knowledge gap, and to determine the best methodology to improve team training for aircraft maintenance technicians.

6.3 RESEARCH OBJECTIVES

The general objective of this research was to understand the role of team training and specifically that of computers for team training. As part of this effort, a computer-based team training software -- the Aircraft Maintenance Team Training (AMTT) software -- was developed and a controlled study was conducted to evaluate the effectiveness of computers for team training.18 The study evaluated the transfer effects of computer-based team training and addressed usability issues related to using computers for team training. In addition to the above general objectives, the research also tested the following hypotheses using the controlled study.

1. Does there exist any difference in the performance of the AMT teams when training is delivered through traditional instructor-based training (IBT) versus computer-based training (CBT-AMTT) format?
2. Is the effectiveness of a specific training delivery system sensitive to task type?
3. Do AMT teams which exhibit superior team performance also demonstrate superior task performance?

6.4 COMPUTER-BASED TEAM TRAINING - THE AIRCRAFT MAINTENANCE TEAM TRAINING (AMTT) SOFTWARE

The efforts to develop a computer-based team training software for aircraft maintenance technicians (AMT) started in September 1994. The earlier phase of the work investigated the usefulness of team training for aircraft maintenance technicians, and developed a framework for understanding the role of teams and teamwork in the aircraft maintenance environment.18,19 Furthermore, this study identified opportunities for incorporating team training within the A&P school curriculum. The results of a controlled study conducted to evaluate the effectiveness of team training were encouraging as to the potential of improving AMT team performance and overall task performance.20 Drawing from the results of this previous research, a computer-based team training software -- Aircraft Maintenance Team Training Software (AMTT) -- was developed.

To ensure that the software addressed the needs of the aviation community, the designers worked in close cooperation with a major aircraft maintenance/repair/overhauling facility and an A&P school. The development of AMTT was based on the classical iterative software/instruction development methodology.21 The requirements of the aircraft maintenance environment guided the development of the software program, which was centered on human (AMT) requirements and evolved through appropriate stages of specification, story-boarding, prototyping, development, and testing.

6.4.1 Layout of the AMTT Software

Specifically designed for training aircraft maintenance technicians in basic team skills, AMTT uses a multimedia presentational approach with interaction opportunities between the user and the computer. The multimedia presentation includes: full motion videos, which provide real life examples of proper and improper team behavior, photographs and animation, that illustrate difficult concepts, and voice recordings coupled with visual presentations of the main contextual material. Since the software was developed as a training and research tool, the software facilitates the collection of pre-training and post-training performance data.

AMTT is divided into four major programs: Team Skills Instructional Program, Instructor's Program, Printing Program and the Supplemental Program. Figure 6.1 shows the overall layout of the AMTT software. While the Team Skills Program and the Supplemental Program have been designed for use by the aircraft maintenance technician undergoing team training, the remaining two programs are for use by the instructor/supervisor. An AMT interacting with the AMTT software, first, uses the Team Skills Instructional program which initially provides an introduction to the software. Following this step and introduction to the software, the AMT is provided with instruction on basic team skills through four team skills sub-modules: communication, leadership, decision making, and interpersonal relationship. These sub-modules not only emphasize and cover generic material related to these skills but also relate the importance and use of the specific skills within the aircraft maintenance environment. On completion of the team skills modules, the information is summarized in the team skills overview module. At this stage, the AMT is ready to use the Task Simulation module, which allows the AMT to apply the skills acquired in the previous four team skills modules within an aircraft maintenance situation. The simulation enables the instructor to test the AMT's knowledge on teams and ability to identify team related problems. In addition to the four basic team skills module, AMTT also provides the AMT with a supplemental program. The supplemental program consists of two separate supplemental modules: the critical path method and interactive decision making. The objective of the supplemental modules is to provide users with hands-on experience in the use of the specific decision making tools in a simulated team environment. It is anticipated that this interactive experience will enhance learning and the use of the above-mentioned tools in the real world environment. Since the software was developed as both a training and research tool, the software facilitates the collection of pre-training and post-training performance data. The instructor can access and analyze user performance data using the instructor's program. The printing program is an additional utility provided to the instructor to print the various screens in each of the team skills modules and present the information in an alternate instructional format.

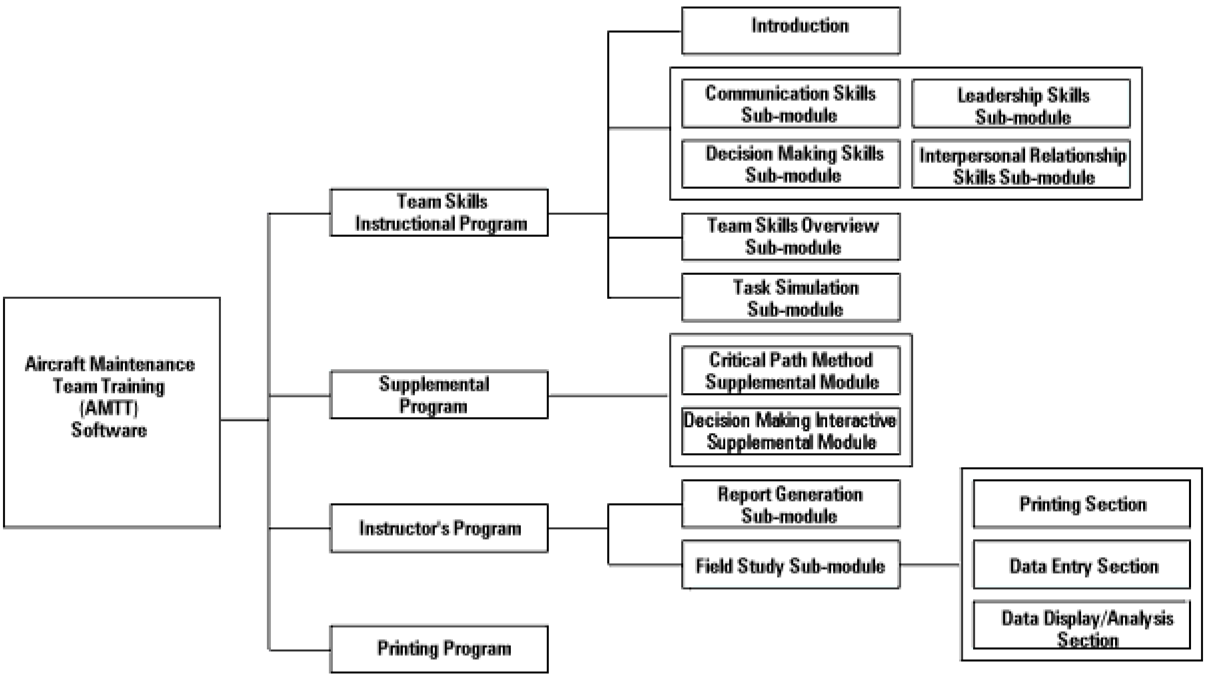

Figure 6.1 Layout of the Aircraft Maintenance Team Training (AMTT) Software

6.5 METHODOLOGY

A controlled study was conducted to evaluate the effectiveness of advanced technology for team training. the following section describes the test site, participants, equipment, and experimental procedures used in this study.

6.5.1 Test Site

The controlled study was conducted at the Aircraft Maintenance Technology Center of Greenville Technical College (GTC). The center houses both classrooms for A&P training and a fully equipped hangar for conducting aircraft maintenance and repair. The classrooms at the Aircraft Maintenance Technology Center provide seating for 20 students. Each classroom is equipped with a 25-inch color television, video player, overhead projector, white and black boards, and a lectern. In addition, the classrooms are equipped with four Pentium 75 MHz computers and 15-inch color monitors (1024 X 768 resolution) installed with multimedia packages.

6.5.2 Test Subjects

The subjects for this study consisted of 12 students from the aircraft maintenance technology center and 24 licensed A&P mechanics from a local aircraft maintenance facility. The subjects were compensated for their participation. The 36 subjects were randomly assigned to two groups such that each group had equal numbers of subjects from the aircraft maintenance technology program and maintenance facility, respectively.

> Group IBT - Instructor-based Training: received team training instruction through traditional instructor-based training (IBT), and
>
> Group CBT - Computer-based Training: received team training instruction through multimedia computer-based training (CBT) software (AMTT software).

6.5.3 Equipment

Table 6.1 provides a list of the equipment used in the controlled study. To keep the two training delivery systems as similar as possible, the video clips used in the IBT were identical to the video clips used in the CBT. In addition, the transparencies used in the IBT were screen dumps from the screen images presented in the CBT.

Table 6.1 Equipment used

Research Phase	Equipment
Instruction Phase	**Overhead projector with transparencies**
Instructor-based Training (IBT)	**Television with video player**
	White board
	Lectern
	Video
	Miscellaneous paper and pencils
Instruction Phase	**Four Pentium 75 MHz computers with full multimedia package**
Computer-based Training (CBT)	
	Aircraft Maintenance Team Training (AMTT) software

Evaluation Phase	**Two King Air 90A twin engine turboprop aircraft**
	Tow tug
	Tow bar
	One set of low platform scales for weighing
	Circuit tester
	Miscellaneous hand tools (e.g. wrenches, screwdrivers, level, string, etc.)

6.5.4 Experimental Procedure

The study was divided into two phases: the instructional and evaluation phases.

Instructional Phase

Team Training

Subjects in the IBT group were trained on team concepts using a traditional instructor-based training delivery system, while those in the CBT group received similar training on a computer using the AMTT software. Every effort was made to maintain a constant curriculum and presentation sequence for both the groups. The only difference in the training between the two groups was the delivery system. The team skills training focused on the following four separate skills: communication, decision making, interpersonal relationship, and leadership. It should be noted that in the instructional phase, team training was provided to individuals.

Data Collection

Before training, each subject completed a demographics report (Section 6.11.1). The subject's perception on each team skill (communication, decision making, interpersonal relationships and leadership), before and after training was measured using the Team Skills Verbal Protocol Report (Section 6.11.2). The report used elements from Crew Resource Management/Technical Operations Questionnaire (CRM/TOQ), the modified Taggart's questionnaire,22 Taylor's questionnaire,23 and the Critical Team Behavior Form (CTBF).24 Similarly, changes in subject's team skills knowledge was measured using a 20-question multiple choice Knowledge Test administered before and after training (Section 6.11.3).

At the conclusion of training all subjects completed a two-part usability report (Section 6.11.4). The report collected subjective satisfaction ratings on the training delivery system using a seven-point Likert scale, where seven indicated strongly agree and one indicated strongly disagree. The first part of the usability report, referred to as the General Report, addressed issues relevant to both training delivery systems, and was completed by subjects in both the groups. The General Report addressed usability issues related to content, mechanics of presentation, format, and usefulness. The second part of the usability report was training delivery system specific, and addressed usability issues related to presentation and format. It was completed by subjects in the respective groups.

Evaluation Phase

The teams were not formed until the evaluation phase. The phase examined the transfer effects of team training (IBT and CBT) on AMT performance. After completion of individual training in the instructional phase, subjects in each group were randomly assigned to six three-member teams. Following the assignments, the teams were tasked with performing two tasks representative of normal aircraft maintenance.

Task 1 Routine maintenance task -- determining the center of gravity of an aircraft.

Task 2 Non-routine maintenance task -- trouble shooting an electrical problem on an aircraft.

The specific tasks were selected after detailed discussions with instructors, mechanics and training personnel at the A&P School and the maintenance facility. The order in which the tasks were performed was balanced within each group so that three teams performed the routine task followed by the non-routine task, while the order was reversed for the remaining three teams. The tasks are described in greater detail below.

Routine Maintenance (RM) Task

As part of the routine maintenance task, each team was tasked with determining the center of gravity of a King Air 90A aircraft. This is a normal routine maintenance activity which is conducted periodically on all aircraft. This task was selected since it requires a team effort to execute. To reflect a true maintenance environment, work cards were supplied to the teams which provided general procedural instructions. For evaluation purposes, the routine maintenance task was subdivided into four major subtasks:

Subtask 1.1 - Towing

Subtask 1.2 - Setup

Subtask 1.3 - Weighing and calculating

Subtask 1.4 - Roll out.

Weighing an aircraft to determine the center of gravity requires that the aircraft be located in a level and enclosed area (hanger) with all doors and windows closed. This is to prevent the movement of air over the wings which may cause the scales to misread the true weight of the aircraft. The aircraft was positioned outside the hanger on the runway apron. As a result, the team's first task (Subtask 1.1) was to tow the aircraft into the hanger. This task required that one person drive the towing tug while the other two team members walk at the wing tips to prevent accidental damage to the plane. This task was considered to start upon receipt of the work cards explaining the procedure, and was deemed finished when the aircraft was positioned and secured in the hanger.

The setup for weighing (Subtask 1.2) started the moment Subtask 1.1 ended, and required the team to secure the platform scales from the storeroom, to position the scales in front of the landing gears, and to roll the aircraft onto the scales. This procedure required one person to drive the towing tug, another team member to ride the brakes in the cockpit, and the third team member to monitor the movement of the aircraft in order to prevent accidental damage to the aircraft. Positioning the chocks for and aft of the wheels, as well as riding the breaks was critical for the safety of the aircraft and the maintenance personal during the setup procedure. This subtask was considered complete when the breaks were set, the chocks were in place, and the tow bar was disconnected from the aircraft.

The weighing and calculating task (Subtask 1.3) started at the conclusion of Subtask 1.2. Prior to reading the scales, the team members followed the procedures given in the work cards requiring that all excess equipment and material be removed, that the plane be leveled, and that all panels and doors be closed. The leveling of the aircraft was accomplished by adjusting the air pressure in the wheels. Once all the steps listed in the work cards were accomplished, the scales were read to obtain the weight of the aircraft. This task was considered complete when the team submitted their calculations to the evaluators. Since it was not necessary for the aircraft to remain on the scales during the calculations, Subtask 1.4 was typically initiated and completed before Subtask 1.3 was completed. The time to complete Subtask 1.4 was subtracted from the overall time taken for Subtask 1.3 in order to obtain a true measure of the completion time for Subtask 1.3.

Roll out (Subtask 1.4) was the final task performed by the team. This subtask started when the team initiated the reconnection of the tow bar to the aircraft, and was deemed finished when the aircraft was moved completely off the scales and parked properly (wheels chocked), and the scales and miscellaneous equipment were put away. As with the set up (Subtask 1.2), this procedure required a team effort with one person driving the tug, a second person riding the breaks and a third person monitoring the aircraft's movement.

Non-routine Maintenance (NM) Task

The second task was a non-routine maintenance task that involved trouble-shooting an electrical problem. To ensure consistency throughout the experiment, each team was read a narrative from a pilot's log that described the problem with the nose landing gear warning light (Section 6.11.5). According to the pilot's log, on final approach to the airport the nose landing gear warning light indicated that the nose landing gear was not down and locked when in fact it was. It is interesting to note, that this is not an untypical problem faced by pilots. The narrative was then left with the team so that they could refer to it as needed. The team had to diagnose the problem, identify/find the problem, and rectify the problem within a one-hour time period. This was an open-ended problem and, therefore, no guidance (i.e., work cards) was provided.

To make this non-routine maintenance problem more challenging, it was subdivided into three separate but overlapping problems. To create the first problem, the circuit breaker for the landing gear lights was placed in the "off" position. If the team managed to solve this first problem, they were still faced with a landing gear warning light that would not function. A second problem was created by placing a burned out bulb in the landing gear light socket. Solving this second problem, the team would continue to face a warning light that would not function. For the third problem, the wire connecting the down and locked switch on the landing gear to the landing gear warning light was disconnected. The disconnection was made inside an electrical junction box located within the nose landing gear wheel well. This third problem was not as obvious as the first two problems, and necessitated the use of wiring diagrams located in the maintenance manual.

Data Collection

As the teams performed the routine and non-routine tasks, their performance on the tasks was evaluated by three independent evaluators on measures of: accuracy, safety, and speed. In addition, at the conclusion of the routine and non-routine maintenance tasks, the evaluators and each individual subject completed a report evaluating their team on the application of various team skills (communication, decision making, interpersonal relationships, and leadership).

Task Performance Evaluation

Routine Maintenance (RM) Task

Accuracy	Number of errors or number of times the team's procedure differed from the work card. Number of time an improper tool was used. Number of times that the equipment was handled incorrectly.
Safety	Number of times the safety of the aircraft was in jeopardy. Number of times the safety of an individual was in jeopardy.
Speed	Time to complete the subtask (in minutes). Percent of task completed within allowed time.

Non-routine Maintenance (NM) Task

Accuracy	Was the problem diagnosed correctly? Did the team locate the problem? Did the team fix the problem?
Speed	Time taken to diagnose the problem. Time taken to locate the problem. Time taken to fix the problem. Total time.
Safety	Number of time the safety of the aircraft was in jeopardy. Number of time the safety of an individual was in jeopardy.

Instructor's Evaluation

Upon completion of the routine and non-routine maintenance tasks, the evaluators completed a verbal protocol report evaluating the teams on various team performance measures (communication, decision making, interpersonal relationships and leadership skills). The instructors evaluated each team on the application of team skills using a seven point Likert scale (Section 6.11.6). The score for each team was obtained by averaging the scores provided by the three evaluators.

Self Evaluation

Upon the completion of the RM and NM tasks, all subjects completed a verbal protocol report that was identical to the instructor's report. This allowed the individual team members to rate the performance of the team on the application of team skills (communication, decision making, interpersonal relationships and leadership).

Scenarios

A team that works together for three hours in a controlled study will not face all the situations that could occur in a real world maintenance environment. To assist in evaluating the performance of teams on both the routine maintenance and non-routine maintenance tasks, certain events which are typical of the aircraft maintenance environment were artificially created (Section 6.11.7). These artificial events (scenarios) forced the teams to employ the team skills and provided a basis for evaluation.

6.6 RESULTS

This section presents the results obtained from the instructional and evaluation phases of the study. Statistical Analysis Software (SAS) was used to analyze the data obtained for the different measures.

6.6.1 Instructional Phase

To measure the effect of team training on a subject's perception of team skills, the responses on the Team Skills Perception report were analyzed using an analyses of variance. Separate aggregate scores were obtained for each individual skills component after ensuring that it was appropriate to group the scores on individual responses into an aggregate measure.25 The ANOVAs (analysis of variance) showed a significant Trial effect for communication [$F(1,34) = 9.37$, $p < 0.05$] and leadership skills [$F(1,34) = 10.44$, $p < 0.05$]. However, the main effect of Trial was not significant for interpersonal relationship and decision making skills. The analysis did not reveal any significant Group x Trial interaction effect or Group effect for any of the team skills.

Similar ANOVAs were conducted on the pre- and post-team skills knowledge test scores to measure the effect of training. The ANOVAs showed a significant Trial effect for communication [F (1,34) = , $p < 0.001$], decision making [$F(1,34) = 112.10$, $p < 0.001$], interpersonal relationships [$F(1,34) = 42.1$, $p < 0.001$] and leadership [$F(1,34) = 14.36$, $p < 0.001$]. The Group x Trial interaction effect and the main effect of Group were not significant. Both the groups showed an increase in the post-training scores.

The subject's responses on the usability reports were analyzed to measure user satisfaction with the training delivery system. Aggregate scores were obtained for each usability category after ensuring that it was appropriate to group the scores on individual responses into an aggregate measure.25 Separate ANOVAs were conducted for each usability category (general categories: content, mechanics, layout, usefulness; delivery system specific categories: presentation, format). The analyses of variance conducted on the general part of the usability questionnaire did not reveal any significant differences between the groups on each of the four general usability categories. A two-tailed t-test was used to compare the actual mean scores versus expected mean scores (3.5) on delivery system specific issues. The tests revealed that the subjects rated both training programs significantly high on presentation and format related issues.

6.6.2 Evaluation Phase

The subjects and instructors evaluated the teams on their application of team skills. Aggregate scores were obtained for each individual skill measure after ensuring that it was appropriate to group the individual responses into an aggregate score. ANOVAs conducted on the aggregated self evaluation scores for communication, decision making, interpersonal relationships, and leadership did not reveal any significant differences between the IBT and CBT trained teams for both the routine and non-routine maintenance tasks. A similar result was also observed on the instructors' evaluation of the teams on the various team skills measures.

ANOVAs conducted on the accuracy measures for the routine maintenance task as a whole did not reveal any significant differences between the IBT and CBT trained groups. Separate ANOVAs were conducted for individual subtasks. The ANOVA showed a significant group effect for subtask 1.1 ($F(1,10) = 4.96$, $p < 0.05$). Similar ANOVA conducted for the non-routine task did not reveal any significant differences between CBT- and IBT-trained groups. Analysis of safety scores for the routine and non-routine maintenance task revealed that both the teams had equal number of safety violations. Separate ANOVAs were conducted on individual speed measures for the routine and non-routine maintenance task. The ANOVAs did not reveal any significant group effect.

Correlation analysis performed on the various measures showed a positive correlation between the post training knowledge test scores and the time to complete the maintenance tasks ($r = 0.4683$, $p < 0.05$)**,** between accuracy measure and the use of communication skills ($r = 0.4322$, $p < 0.01$), decision making skills ($r = 0.341$, $p < 0.05$) and interpersonal relationship skills ($r = 0.4661$, $p < 0.0042$). Similarly, correlation analysis of safety scores revealed that the teams which had higher communication, decision-making, leadership, and interpersonal relationship scores had significantly fewer safety violations
($r = -0.5702$, $p < 0.001$; $r = -0.8062$, $p < 0.0001$; $r = -0.5312$, $p < 0.0009$; $r = -0.4719$, $p < 0.0112$).

6.7 DISCUSSION

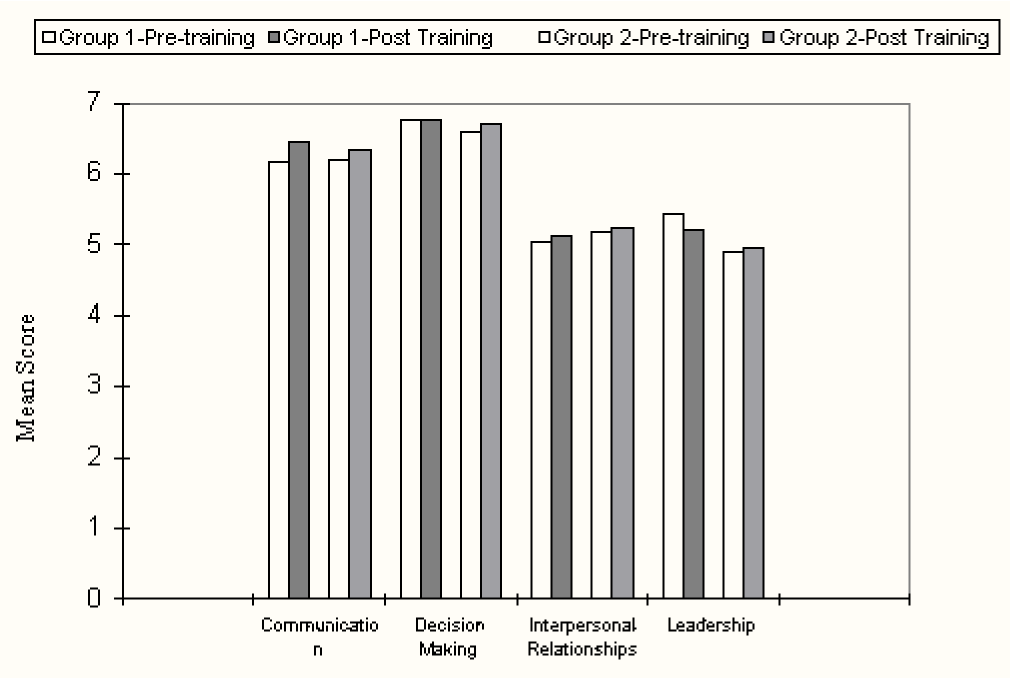

Figure 6.2 Comparison of Team Skills Perception Pre- and Post Training for Groups 1 and 2

The analyses of the pre- and post-training perception questionnaires showed that the training delivery system had comparable effects on the subject's perception of team skills. It was interesting to note that the subject's overall (pre- and post-training) perception of interpersonal relationships and leadership skills were much lower than those for communication and decision making skills (Figure 6.2). The subjects that made up the test Groups consisted of either students or maintenance technicians, and as such were not composed of crew leads or supervisors. It can be hypothesized that nonsupervisory technicians do not recognize the importance of leadership and interpersonal relationship skills. This lack of concern for leadership skills was first noted by Taylor.7 In a survey of ten U.S. commercial transport aviation maintenance facilities, Taylor found a lack of leadership skills in maintenance foremen. In addition, work currently being conducted under a grant from the FAA Office of Aviation Medicine has identified a need for leadership skills training for lead mechanics and maintenance foremen.26

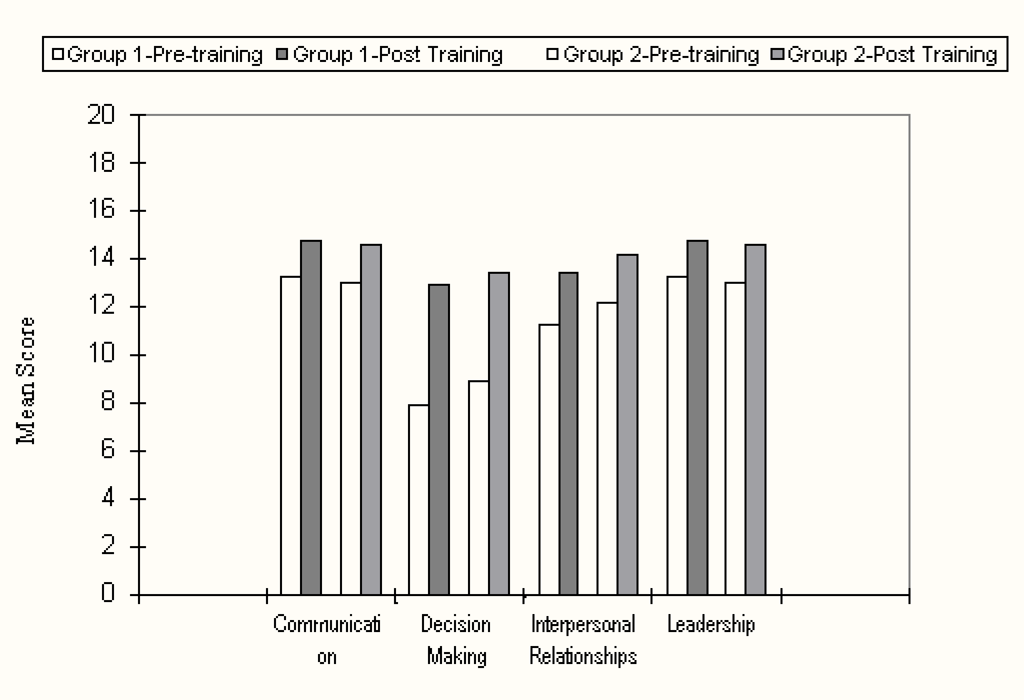

Figure 6.3 Comparison of Team Skills Knowledge Tests Pre- and Post Training for Groups 1 and 2

Both the IBT and CBT groups showed a significant increase in the post-training knowledge test scores (Figure 6.3). The highest increase in score was observed for the decision making skill (Group IBT: 64 percent, Group CBT: 50.1 percent), followed by interpersonal relationship (Group IBT: 19.1 percent, Group CBT: 16.4 percent), and almost an equal increase in scores for communication (Group IBT: 11.3 percent, Group CBT: 12 percent) and leadership skills (Group IBT: 11.3 percent, Group CBT: 12 percent). The fact that both groups showed comparable increases in test scores probably indicates the effectiveness of both methods of delivering team training. The results are consistent with those of other researchers who have found similar results in improving team skills by training. Taylor et al., conducted a crew resource management (CRM) training program for aircraft maintenance personnel and found that maintenance performance measures increased after training. 27 Also, in a study to improve teamwork in engineering design education, Ivaturi found that team training instruction enhances student's knowledge of team skills.19

Traditionally, team training has been delivered in a classroom environment by role playing, games, simulations, etc.17,28 Thus, the conventional approach has been highly interactive wherein the trainees and trainers interact at different levels throughout the training process. The fact that the CBT (specifically, the AMTT software) was able to achieve the same scores as IBT (an equally well designed instructor-based team training program) bodes well for the role of computers in imparting team skills knowledge. At this point, it should be mentioned that the IBT portion of the team training program had the same content as the CBT portion and the only difference was in the method of delivery. This shows that given the equivalent content of the two team training programs, a well designed interactive computer-based team training program can be as effective as a traditional instructor-based team training program.

The development of the AMTT followed an iterative design process so that the problems with the software were identified and corrected before implementation. The cycle of design, test, measure, and redesign was repeated numerous times in the development process.21 Thus, the AMTT software was developed after understanding the needs of the AMT, talking with experts from Lockheed Martin and Greenville Technical College, following a process of iterative design and development, and eventually resorting to detailed user testing (with instructors, supervisors and AMTs). The usability and knowledge test scores clearly indicate that the resulting product was one which was well received by the users and one that helped increase their knowledge on the teamwork skills. Figure 6.4 shows the results of the general usability questionnaire with mean scores on four separate usability issues. These results are encouraging since they indicate that the users were equally satisfied with both training programs. Chandler found similar results using a media rich computer software (System Training for Aviation Regulations - STAR) to teach federal aviation regulations (FARs) to A&P students.29 In her study, the subjects reported a high degree of satisfaction with interactive stories and true-to-life situations presented through CBT. Comparable satisfaction levels between users of hypermedia and paper-based team training programs were also noted by Ivaturi.19

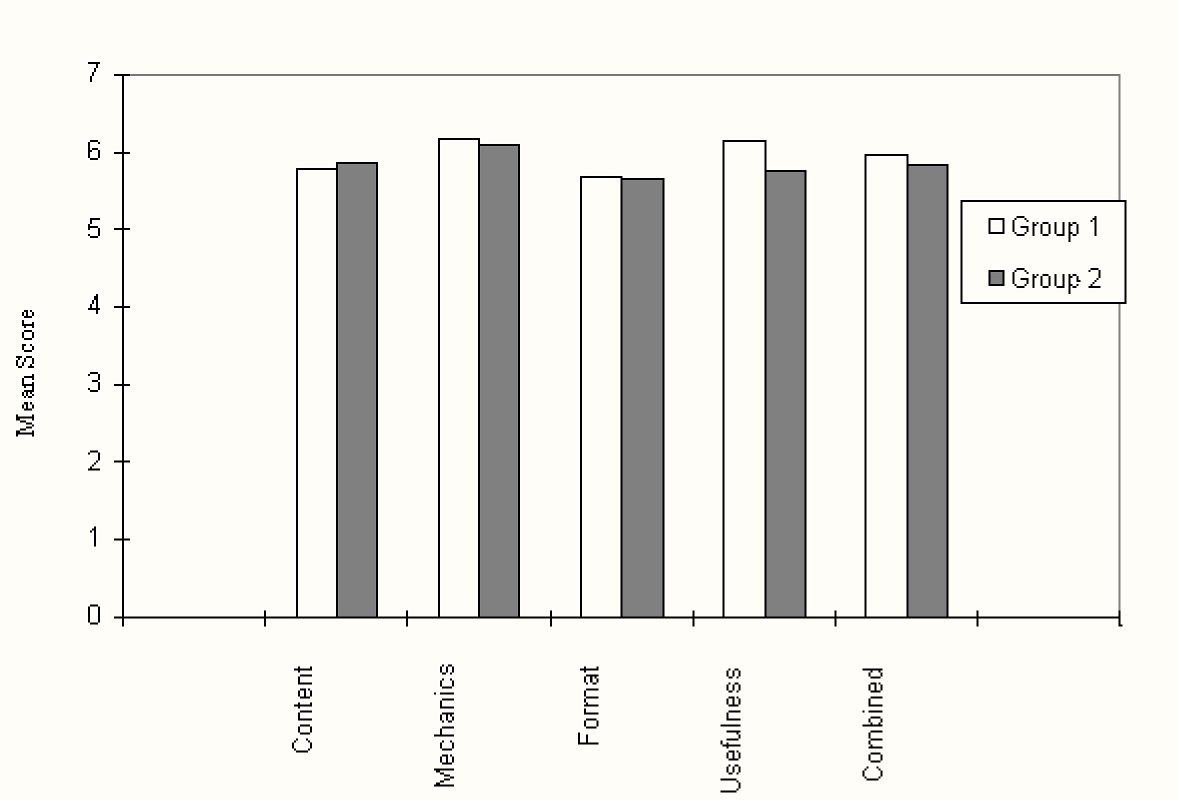

Figure 6.4 Comparison of Usability Scores for Groups 1 and 2 on Training Delivery Issues

The self evaluation scores on each team skill category were similar for both the groups on the routine and non-routine maintenance tasks. The results indicate that the effect of both the training programs on the teams perception of their application of team skills are comparable. Similarly, instructor's evaluation on the application of team skills was comparable for both the routine and non-routine maintenance tasks. It is interesting to note that for each skill category in the routine and non-routine maintenance tasks, the instructors were conservative in their ratings compared to the subjects' ratings. A similar result was noted by Glickman et al., in a study examining the development of team skills over time.24 In their study, the instructors ratings were consistently lower than the rating given by the team leader.

Analysis of accuracy scores on the routine maintenance task revealed that the total number of errors were the same for each Group (10 each). Most of the errors were due to the fact that the team's procedures differed from those specified in the work cards. Table 6.2 gives a breakdown of the typical errors made by the teams while performing the routine maintenance task. Accuracy for the non-routine maintenance task was measured by whether or not the teams correctly diagnosed the problem (Yes or No), located the problem (Yes or No) and fixed the problem (Yes or No). All 12 teams diagnosed, located, and fixed Problems 1 and 2. Only two teams (T1 and T6) could not locate and fix Problem 3 within the allocated time. Statistically, there were no significant differences between the Groups, indicating that the training delivery system had no effect on the accuracy measures. A positive correlation was observed between the accuracy and the use of communication skills, decision making skills, and interpersonal relationship skills. These findings are consistent with other studies on the effects of communication and decision making on team performance. In a study of the Team Evolution and Maturation model, Morgan, Salas and Glickman found that as a team's performance improves, the perception of the team members concerning communication and coordination increases.30 Also, in a study to investigate whether teamwork process measures are associated with outcome measure, Brannick et al., found that team effectiveness was positively associated with decision making and communication skills.31

Table 6.2 Typical Accuracy Errors that Occurred During the Routine Maintenance Task

Subtask	Typical Errors that Occurred
	• Failed to check oil and to drain toilet waste water

Subtask 1.1 - towing	system • Failed to close hanger doors
Subtask 1.2 - set up	• Failed to place all control surfaces in neutral position • Failed to close passenger door
Subtask 1.3 - weighing and calculating	• Failed to measure from the main wing spar • Made incorrect measurement from the wheel center line to reference datum
Subtask 1.4 - roll out	• Failed to properly place chocks • Failed to return scales to storage

An obvious revelation after analyzing the accuracy scores for the routine and non-routine maintenance tasks was the overall low number of errors for both the Groups. The high accuracy scores achieved by the teams can probably be explained within the Speed Accuracy Tradeoff (SATO) context.[32] Training delivered at A&P schools and through various training departments focuses on accuracy, emphasizing the need to minimize errors since these can be catastrophic (e.g., the case of a Continental commuter airlines, Continental Express, that flew without the tail deicing boot properly attached, or the United DC-10 whose engine failed, severing control hydraulic lines and causing a crash at Sioux City). This perception of accuracy obviously seemed to transfer to the performance of the teams for both the RM and NM tasks.

Both the Groups had almost the same number of safety violations for the routine and non-routine maintenance tasks. The majority of the safety violations occurred for the RM task. Table 6.3 provides a list of typical safety violations that occurred during the routine and non-routine maintenance tasks. The lack of safety violations during the non-routine maintenance task could possibly be an artifact of the task. The NM task was essentially a problem-solving task. Therefore, the task was more of a cognitive task unlike the routine maintenance task which was a highly procedural and manual task (movement of the aircraft into the hangar, positioning the aircraft, and rolling the aircraft onto and off of the scales). Hence, the opportunities for safety violations were much greater for the RM task compared to the NM task. Although safety violations were reported for RM and NM tasks, the overall number of incidences were much lower than those that are typically reported in the "real world" aircraft maintenance environment. [33,34] The existing study was performed in a clean, quiet, and simulated hanger environment. There were no other AMTs working on the aircraft at the same time, thereby minimizing work interruptions and work flow. On an actual hangar floor, there are multiple skill groups (avionics, hydraulics, maintenance) with multiple crews working on a single aircraft. It is a highly complex and dynamic environment wherein an individual AMT must not only work with his own team members, but also must communicate and coordinate with other crews, supervisors, inspectors, etc. Thus, the work of a team is not only dependent on the intra-team factors, but also inter-team factors. In addition, there are other factors which are obviously present: environmental factors (e.g., poor noise and lighting conditions), organizational factors (e.g., gate pressure, late night shift), and subject factors (e.g., part-time workers, shift workers), which were missing in the current study, and possibly contribute to the greater number of safety violations. Similarly, the results of the statistical test did not reveal any significant differences between the IBT and CBT trained teams on overall task completion times for the routine and non-routine maintenance tasks.

Table 6.3 Typical Safety Violations that Occurred During the Routine and Non-routine Maintenance Tasks

Tasks	Typical Safety Violations
Routine Maintenance Tasks:	

Subtask 1.1 (towing)	• **Removed wheel chocks prior to connecting towing tug** • **Failed to walk with the aircraft while towing it to the hanger**
Subtask 1.2 (roll up)	• **Failed to place chocks fore and aft of the scales** • **Failed to properly set parking brakes**
Subtask 1.3 (weighing and calculating)	• **No safety violations**
Subtask 1.4 (roll out)	• **No safety violations**
Non-routine Maintenance Tasks:	
Problem 1 (circuit breaker)	• No safety violations
Problem 2 (burned out bulb)	• No safety violations
Problem 3 (disconnected wire)	• Caused damage to junction box • Replaced wire without first checking wiring diagram in the maintenance manual

6.8 CONCLUSIONS AND FUTURE EXTENSIONS

Having discussed the results from the analysis and evaluation phases of the study, the following conclusion can be drawn from the study.

- There were no significant differences between IBT and CBT in terms of user satisfaction. Both the training delivery systems reported a high level of user satisfaction on the general and delivery specific portions of the usability questionnaire. Analysis of the general usability questionnaire on specific issues such as content, mechanics, format, and usefulness did not reveal any significant differences between the two training delivery systems. It was encouraging to find that AMTs were able to interact and use the AMTT software after minimal instructions on basic computer operations.

- Team training enhanced the knowledge of individuals on team skills. However, the type of training delivery system did not have a significant effect on the individual's ability to acquire team skills knowledge and apply the knowledge acquired. Both the systems were comparable in terms of their ability to deliver team skills knowledge.

- Teams which exhibited superior team behavior also exhibited superior performance on a select set of task performance measures. The correlation analysis showed that the results approached significance for a large number of variables.

- Many times CBTs fail because software designers fail to design interfaces and systems that the users can understand. The problem can be alleviated by resorting to a user-centered design approach which uses an iterative process of design, test, measure, modify, and retest. This procedure was used in the development of the AMTT software, and as such a user friendly product was produced. The study used subjects with limited computer experience, yet they were able to interact with the AMTT software without assistance.

- After analyzing the results for both the CBT and IBT teams, the results are unequivocal. CBT (i.e., AMTT) was as effective in delivering team training instruction as IBT. Finally, the iterative design methodology employed in this study proved to be useful in designing an effective computer-based team training software. The above results have obvious ramifications for the use of AMTT for team training in the aircraft maintenance environment. In addition to being as effective as existing instructor-based team training methodologies, use of AMTT for team training has other obvious advantages:

    1. Standardization: AMTT provides a systematic and consistent curriculum. Aircraft maintenance instructors at various facilities use their own unique training strategies (lectures, classroom discussions, video examples, etc.). In addition, some maintenance instructors who are technically competent may not have sufficient team skills knowledge to train AMTs on teamwork. The AMTT software provides a standardized and systematic team skills training program which aircraft maintenance instructors (at certified repair stations, airline companies, general aviation stations, and A&P schools) can use to provide team skills training.

    2. Adaptability: Traditionally, maintenance training has been accomplished via on-the-job training or classroom training, both of which are manpower intensive. It requires careful scheduling of personnel or encumbers others in the training process. AMTT is adaptive, self paced, and can be done at convenient times when trainees are available and need only involve the person being trained.

    3. Record Keeping: The record-keeping capabilities of AMTT track the student's progress. This information can be used by the instructor/supervisor to design remedial training.

    4. Cost effectiveness: Team training using AMTT can be cost effective because: (1) It can be delivered on-site, thus eliminating travel expenses for the trainer and the trainee. (2) It can minimize down time by providing training at times that are convenient to the trainee and the company's work schedule. In larger organizations, AMTT can be delivered to many people at multiple sites thus proving to be cost effective.

    5. Use of advanced technology: Many facilities (e.g., A&P Schools and fixed based general aviation facilities) do not have access to larger aircraft. The AMTT software provides team skills training against the backdrop of maintaining a DC-9. Therefore, the trainees not only acquire knowledge and skills on teamwork, but also gain an understanding of the importance of teamwork in the maintenance of wide-bodied aircraft.

Based on the results of this study, it is clear that team training needs to be integrated into the existing curriculum of the A&P school as well as the continuing education programs of licensed AMTs. This can be achieved by using multimedia computer-based team training programs (such as AMTT) which focus on both generic and context specific (i.e., aircraft maintenance environment specific) team skills. In addition, we envision the following extensions to the current work:

- A larger study needs to be conducted which will look at the effects of team training in the real world. Furthermore, the study should encompass a wider variety of maintenance tasks (line maintenance, base maintenance, component shops, and support shops) involving various repairs and maintenance facilities ranging from large airlines through fixed based operators associated with general aviation.

- The current study evaluated team performance by measuring changes in outcome measures (accuracy, safety and speed) and team performance variables (self evaluations and instructor's evaluations). This could be viewed as a simplistic way of modeling the team process wherein the changes in the inputs (training programs) are mapped onto changes in the outputs. Although the data obtained from this study provided valuable insights into the team process, we still do not know what changes took place in terms of task process measures (e.g., changes in the mental model, number of dead ends in trouble shooting a problem, etc.) that had an impact on the outcome measures. Hence, it would be worthwhile to extend the current study so as to look at team process measures, task process measures, and outcome measures as teams perform a series of aircraft maintenance related team tasks.

- The current study looked at the immediate effects of team training, but did not examine the long term retention of team skills. A study is needed to examine whether team skills degrade over time, and if so, what interventions (e.g., retraining or remedial training) should be applied to reverse this trend.

- In the current study, knowledge on team skills was delivered to individuals. Future research should examine the possibility of creating a multimedia computer-based team training software program which would deliver training to teams rather than to individuals. The future version of the AMTT software should expand the individualized team skills training to significantly larger teams with team roles being performed either by the human or the computer.

- The current study demonstrated the effectiveness of interactive multimedia computer-based team training. As newer interactive computer technology becomes more readily available, there will be new opportunities for research.

    1. Over time team training environments will become more real and possibly more fun. Development of 3D game environments would allow individual or multiple users to acquire and practice teamwork skills in a real world mode. Current research has used games such as Gunship(tm) and Microsoft Flight Simulator to teach and test teamwork skills,35 but new software programs can be developed which would allow a team of individuals to build a city, explore a new world or troubleshoot an aircraft in flight. Further research is needed to test the suitability of the newer technology with respect to the current CBT and the traditional IBT.

    2. The next obvious step is to incorporate new technology into team training programs. One such futuristic tool which is available today is virtual reality. Virtual reality can enhance learning by allowing the user to "walk through" the environment, examine objects from various perspectives, and to interact with the environment. A study should be conducted that would examine the effectiveness of using virtual reality in developing high fidelity computer-based team training programs.

    3. Future versions of the AMTT software should provide for expanded communication with full use of networked computers and/or internet. AMTs could work with their colleagues from different sites and apply team skills in solving maintenance-related problems.

6.9 ACKNOWLEDGMENTS

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6.11 APPENDICES

6.11.1 Appendix A - Consent Form

INFORMED CONSENT STATEMENT FOR
TEAMWORK, TEAM TRAINING AND TEAM PERFORMANCE:
AIRCRAFT MAINTENANCE ENVIRONMENT

INFORMATION

You have been invited to participate in a research study entitled Teamwork, Team Training and Team Performance: Aircraft Maintenance Environment. If you agree to participate, you will be one of thirty-six subjects who will be participating in the study. You will be participating both individually and on a team.

There are two distinct stages to this research. In the first stage, you will be asked to be one of two groups: one group will receive team training in a traditional classroom format, and the other group will receive training from a computer-based multimedia team training tutorial. Both training delivery systems will provide you the same information.

Prior to any instruction, you will be asked to fill out some personal demographic information. ALL

INFORMATION WILL BE STRICTLY CONFIDENTIAL.

You will also be asked to complete a short questionnaire and multiple choice test both before and after each instructional unit. The scores on your test and your opinions about the topic will not be revealed to anyone other than yourself (upon request) and the investigators conducting this research: David Kraus and Anand Gramopadhye.

At the conclusion of all instruction you will be asked to fill out a questionnaire giving us your opinion of the training.

ESTIMATED TIME FOR STAGE 1 = 3 HOURS

In the second stage of this research, you will be assigned to a three member team. As a team you will need to complete two aircraft maintenance tasks: a routine maintenance task and a non-routine maintenance task. Major equipment will be supplied, but you may need to use your own tools. After completion of each task you will need to complete a short questionnaire giving us your opinion of how well your team performed.

ESTIMATED TIME FOR STAGE 2 = 3 HOURS

You will be paid $5.00/hour for your time. Payment will be upon completion of the testing.

For those of you receiving training from the computer, there may be feelings of frustration. It will be extremely helpful if you tell us about these times so that we may correct any problems. Please remember, that any frustration you feel is due to the difficulties in the software and not because you have done anything wrong.
We can only test two teams at a time during the second stage. Therefore:

AFTER COMPLETING STAGE 2 OF THIS RESEARCH

PLEASE DO NOT INFORM THOSE WHO HAVE YET TO DO THE TASKS WHAT THE TASKS ARE OR ANY PROBLEMS YOU MAY HAVE HAD

CONSENT

I have been given the opportunity to ask questions about this study; answers to questions (if any) have been satisfactory.

The information in the study records will be kept confidential and will be made available only to persons conducting the study unless I specifically give permission in writing to do otherwise. In any results of this study that are published, I will not be identified.

I will receive $5.00 per hour to a maximum of 6 hours ($30.00) even though the actual time spent in receiving instructions and performing tasks may vary.

In consideration of all of the above, I give my consent to participate in this research study. I understand that I may drop out of this study at any point if I so choose.

I acknowledge receipt of a copy of this informed consent statement.

SIGNATURE OF SUBJECT_______________________________________

DATE________________________________

SIGNATURE OF WITNESS____

SIGNATURE OF INVESTIGATOR______________________________

6.11.2 Appendix B - Team Skills Verbal Protocol Report

Perception Questions on Communication

1. Good communication and team coordination are as important as technical proficiency for aircraft safety and operational effectiveness.

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

2. Crew leaders and supervisors should encourage questions during work and in special situations

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

3. The start of shift team meeting is important for safety and effective team management

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

4. Knowing the correct technical terminology is critical for effective communication

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

5. Proper team communication should always be unidirectional and progress from the crew chief down to the team members.

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

6. If a person is not able to perform the job properly, he should ask for help from the team members

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

7. Positive feedback is more important than negative feedback.

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

8. Team members should give unsolicited advice to each other on how to do a job.

Very strongly disagree 1 2 3 4 5 6 7 Very strongly agree

9. It is equally important to know how to give feedback as well as to receive feedback.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

10. Feedback is necessary for improving team performance.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

Perception Questions on Decision Making

1. Team members should not question the decisions or actions of the crew leader or supervisor except when they feel that the action could effect the safety of the operation

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

2. In a team situation the work goals and priorities have to be agreed upon by all team members.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

3. All team members should contribute to the team decisions

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

4. In making decisions in a team it is important that all members participate

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

5. If there exists a conflict it should be resolved by the team leaders.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

6. Team members should actively support the goals and objectives of the organization (Costs, quality and service).

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

7. If a team member disagrees with the decisions of the team they should voice their opinions.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

8. Voting and than using the majority is the best way to make team decisions.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

9. Teams have no need to make decisions. They should work together as directed by the crew lead.

Very strongly disagree **1** **2** **3** **4** **5** **6** **7** **Very strongly agree**

10. Brainstorming is an effective ideas generation technique.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

Perception Questions on Interpersonal Relationships

1. Team members should avoid disagreeing with others because conflicts could create tension and reduce team effectiveness.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

2. One should be aware of and sensitive to the personal problems of other team members.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

3. For a team to work effectively it requires every team member to rake into account the personalities of the other team members.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

4. Since individuals do not function as effectively under high stress conditions, team coordination is more important in emergency or abnormal situations

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

5. A member of crew leader who is truly professional will not bring his personal problems on the job.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

6. The team members should help resolve a team members personal problem if it affects the job.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

7. Team members can reduce problems relating to interpersonal relationships by not interfering with the jobs of other team members.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

8. Problems mainly due to interpersonal relationships are management problems and the management needs to address them to help the team.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

9. If there is one member who adversely affects the working of the team, that person should be isolated from the team.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

10. Having good interpersonal relationship skills are important to the success of the team.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

Perception Questions on Leadership

1. The crew leader or supervisor should take hands on control and make all decisions in emergency or non-standard situations.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

2. Team members should not question the decisions or actions of the crew leader or supervisor except when they threaten the safety of the operation.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

3. Under no circumstances should a sub-ordinate assume control of the project.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

4. The responsibilities of the crew leader vary across situations

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

5. Overall successful team management is primarily a function of the crew leader or supervisor's technical proficiency.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

6. For a team leader to have the respect of his team members he should be technically proficient in all aspects of the work.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

7. The crew leader or supervisor should verbalize plans or actions and should be sure that the information is understood and acknowledged by the team members.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

8. T team leader should complete the tasks for his team member if he doesn't know how to complete it.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

9. Knowledge on how to hold a meeting is an important skill of a leader.

Very strongly disagree **1 2 3 4 5 6 7** **Very strongly agree**

10. Unlike technical skills, leadership skills are easily learned and used.

Very strongly disagree

1	**2**	**3**	**4**	**5**	**6**	**7**	**Very strongly agree**

6.11.3 Appendix C - Team Skills Knowledge Tests

Table C-1
Multiple Choice Test on Communication

1. Your crew chief is talking to the team and when he says something significant and you nod your head in agreement...
   A. It displays a lack of desire to communicate.
   B. You are communicating with body language.
   C. You should keep very still so as to not confuse the speaker
   D. You should remain quiet since verbal and non-verbal communication do not mix.

2. Which of the following is the proper sequence of the communication process?
   A. Transmitter, audience, feedback and speaker.
   B. Speaker, paper, reader and feedback
   C. Transmitter, receive, audience and message.
   D. Speaker, message, listener and feedback.

3. A message that a speaker wishes to verbally communicate may be distorted by any of the following EXCEPT...
   A. Background noise.
   B. His attitude to the listener.
   C. Terminology that is used.
   D. The printing cost.

4. Suppose you are presenting some technical information to your team, and you notice that a team member is indicating with his facial expression that he doesn't understand wheat you are saying. You should...
   A. Stop for a moment and ask if you are making yourself clear.
   B. Continue on because he will eventually understand.
   C. He should be ignored since any interruption of your presentation would be rude.
   D. You should stop your presentation to answer his question but only if he requests it.

5. Which of the following is true?
   A. Listening is not considered a true form of communication.
   B. We communicate most often by writing
   C. Feedback is typically not immediate in written communication
   D. Communication by body language is only done by the listener as he responds to the speaker.

6. Which of the following statements concerning active listening is true?
   A. In active listening you should actively consider what you are going to say next while the speaker is talking.
   B. Active listening is disruptive and should be avoided.
   C. Part of active listening is giving feedback to the speaker on what was just said.
   D. Active listening is listening while you are involved in an activity.

7. You are presenting an idea you have to your team. One of your team members is sitting with his ankles crossed, his arms crossed and is looking at the floor. Which of the following concerning this person is true?
   A. He really likes your idea but is waiting patiently for you to finish so he can add a thought.
   B. He doesn't agree with your idea but is being polite by not interrupting.
   C. He is impatient and does not care one way or the other what your idea is.
   D. He is probably indicating that he wants to speak next.

8. When the supervisor summarized what he said and then asked several team members questions, he was...
   A. Grading the team members.
   B. Using an investigative management technique.
   C. Was using reverse psychology to get his team to work harder.
   D. Looking for feedback to see if he got his message across.

9. All of the following are communication EXCEPT...
   A. Reading a circular
   B. Thinking of ways to improve performance
   C. Giving a fellow team member a "Thumbs up" sign

D. Listening to announcements

10. In the communication process, the transfer link or mode...
    A. Should be written
    B. Is spoken
    C. Can be spoken, written, or visual.
    D. Does no include visual.

11. In the communication process, feedback...
    A. Shortcuts the path between encoding and decoding
    B. Does no show up during verbal communication
    C. Is electronically passive
    D. Is used to clarify ideas, intent and concepts

12. All of the following may cause your message to be changed or distorted EXCEPT...
    A. Circulars used
    B. Terminology used
    C. Tone of voice
    D. Background noise

13. Which of the following concerning feedback is true?
    A. Is only a problem in electronic communication.
    B. Should be written down
    C. Should be positive as well as negative
    D. Is not a consideration for job performance

14. Which of the following is NOT a proper guideline for written communication?
    A. Write so that only the most experienced reader will understand.
    B. Proof read any document you write.
    C. Be clear, concise and correct.
    D. Write legibly.

15. Which of the following is a form of verbal communication?
    A. A bulletin
    B. A class presentation
    C. Nodding your head
    D. Smashing your fist on a table because you are mad.

16. Of a circular, bulletin and non-routine work card, which is a type of written communication?
    A. The circular and the bulletin only.
    B. The non-routine work card only.
    C. All are examples of written communication
    D. None are examples or written communication.

17. Feedback is important in job performance because...
    A. It is used by management for grading
    B. It allows you to correct or improve your work.
    C. It is part of your performance evaluation.
    D. It goes on you permanent record.

18. Effective listening techniques include...
    A. Stopping a person as soon as you disagree, so that you can systematically make your points.
    B. Formulate your next point while a speaker is talking.
    C. Assume an attentive position.
    D. Always take notes.

19. In this video, Ron...
    A. Is using an active listening technique.
    B. Is performing interactive management
    C. Should not have spoken since it disrupts John's train of thought.
    D. Failed to use body language.

20. The non-routine work card shown in the picture has created a problem for the reader because...
   A. Of poor English
   B. Of poor handwriting
   C. Of incorrect information
   D. Insufficient information

Table C-2
Multiple Choice Test on Decision Making

1. With reference to the video, what is the first thing that this team must do?
   A. Define the problem as a single question.
   B. Brainstorm ideas.
   C. List reasons why the existing process won't work.
   D. Do a critical path analysis.

2. Which of the following is an example of a well defined problem that this team might develop?
   A. What management practices and training rolls need to be implemented to alleviate this problem.
   B. How can we get the parts to the mechanics in a timely manner?
   C. List the present problems.
   D. What are the overall objectives of this company, and how might those objectives be changed to accommodate changes in the supply department?

3. Which of the following procedures should this team use to generate ideas to improve the process?
   A. Controlled convergence technique
   B. Evaluation by voting
   C. Selective elimination
   D. Brainstorming

4. Which of the following is the second step in the decision making process?
   A. Prioritizing
   B. Problem definition
   C. Generation of ideas
   D. Coordination with supervisors

5. In brainstorming...
   A. You should accept ideas that are generated without discussion or reaction
   B. You should immediately drop ideas that the majority vote to eliminate
   C. You should never combine ideas
   D. The team leader should limit the number of ideas to simplify voting.

6. With reference to the video, what decision making tool is this team employing?
   A. Multivoting
   B. Voting
   C. Nominal group technique
   D. Consensus

7. In the idea generation stage of decision making...
   A. You reject all poor or ridiculous ideas right away to save time
   B. Each idea should be discussed in detail as it is presented
   C. Piggy-backing or hitch-hiking your ideas onto someone else's ideas is encouraged
   D. You should use personal experiences to reject ideas that have failed in the past

8. After a list of ideas have been generated, your team should progress to the third stage in the decision making process. This step is...
   A. Prioritizing
   B. Coordinating
   C. Mechanizing
   D. Supervising

9. Which of the following tools would you use to prioritize the list of ideas the team develops to improve the process?
   A. Consensus
   B. Voting
   C. Multivoting

D. Management by tolerances

10. If your team comes to a solution by unanimous vote, then what was the decision tool that was used?
   A. Consensus
   B. Voting
   C. Multivoting
   D. Nominal group technique

11. With reference to the above video, what decision making tool is this team using?
   A. Multivoting
   B. Voting
   C. Nominal group technique
   D. consensus

12. Why would we want to use a majority voting procedure as a 'decision making' technique?
   A. Because it is good for handling complex situations
   B. Because voting never produces bad feelings
   C. Because it builds self-esteem
   D. Because it is a rapid decision making technique.

13. In the multivoting decision making technique...
   A. You need to vote the same way each time to maintain consistency
   B. You prioritize your votes
   C. You cast you votes in any manner you choose
   D. The number of votes you get is set at 4 per person

14. The silent generation of ideas...
   A. Reflects poor communication skills
   B. Should be done before idea presentation
   C. Is an alternative to brainstorming
   D. Is used at the conclusion of meetings

15. Which of the following statements is correct?
   A. Having a well defined decision making procedure is helpful to a team.
   B. Once a team is finished brainstorming, they will have a consensus as to a solution.
   C. Multivoting is a sub category of inspection.
   D. Of all team skills, decision making is the most important.

16. With reference to the video, what should the team leader so at this point
   A. The team leader should close the meeting and report 'No ideas generated' to the supervisor.
   B. The team leader should keep presenting his own ideas in the hope that the others will get started.
   C. The team leader should use his authority to make them respond.
   D. The team leader should back up and start with the silent generation of ideas.

17. With reference to the video, what should the team leader do at this point?
   A. Do more silent generation of ideas allowing more time - possibly days
   B. Back up to the initial problem and discuss it thoroughly since there is probably some misunderstanding
   C. You must keep going round robin until someone gives an ideas to report. Someone has to say something.
   D. Stop. It is now time to report 'No ideas generated' to the supervisor.

18. With respect to the video, what should the team leader so at this point?
   A. Nothing. This is the type of interaction that you are seeking for eliminating poor ideas and keeping good ideas.
   B. Redirect the focus of the team to another problem that needs to be solved.
   C. Reprimand the team members for criticizing and evaluating
   D. Stop the evaluation by reminding team members of the brainstorming rules.

19. With reference to the video, in this situation, the team leader...
   A. May make changes on a suggestion if the contributor agrees.
   B. Is within his power to make any alterations.
   C. Should make alterations to a suggestion only if the majority of the team members agree.
   D. Should never change what the contributor says.

20. When the team is discussing the various ideas generated during brainstorming, the team leader should...
    A. Uses his discretion to shorten the list of ideas for his team.
    B. Should only eliminate ideas and not combine ideas
    C. Should eliminate or combine ideas only with the permission of the contributor and other team members
    D. Leave the list alone. Do no make changes.

Table C-3
Multiple Choice Test on Interpersonal Relationships

1. Which of the following statements concerning successful teams is true?
    A. Successful teams never have interpersonal relationship problems.
    B. Successful teams consist of people with similar experience, background and opinions.
    C. Since teams are temporary, successful teams must ignore personal differences and avoid all conflict.
    D. Successful teams realize personal differences can add to the strength of the team.

2. In general, teams should...
    A. Avoid uncontrolled tension when dealing with conflict
    B. Encourage conflict between team members
    C. Not avoid conflict or tension since it helps to ensure a free exchange of ideas
    D. Realize that open conflicts are always constructive

3. Team members must learn to...
    A. Respect other team members and consider their opinions
    B. Avoid objectionable remarks
    C. Be open to new ideas
    D. All of the above

4. Team members learn to work together...
    A. Very easily since they are working on a common goal
    B. Through extensive training and close supervision by trainers
    C. With the help of a specially trained manager
    D. Through several stages of development

5. The "Forming" or "first" stage of a team's growth is best characterized by which of the following statements?
    A. There is excitement, optimism and some anxiety.
    B. There are arguments among team members, competition and "choosing sides."
    C. There is significant involvement by top management because this stage is so critical.
    D. Forming is characterized by the large number of forms to be filled during this stage.

6. The "Storming" stage is considered which stage of a team's growth?
    A. First
    B. Second
    C. Third
    D. Fourth

7. Which of the following statements regarding the "Storming stage" of team growth is true?
    A. Successful teams typically by-pass this stage of team growth because of the conflict.
    B. During this "Storming stage," it is vital that management becomes involved.
    C. During this state, more energy is spent in learning about one another than in accomplishing goals.
    D. Storming occurs primarily in long established teams.

8. Which of the following statements regarding the "Norming stage" of team growth is true?
    A. This is the last and fourth stage
    B. During this stage, team members are more friendly and confident in each other
    C. It is at this stage that management becomes involved in each team aspect
    D. Most conflicts occur during this stage

9. Ground rules are used to:
    A. Determine procedures for running a team meeting
    B. Set up processes for documenting team activities
    C. Establishing acceptable behavior
    D. Establishing acceptable behavior and standard operation procedures

10. Gatekeeping is often included in ground rules, and refers to:
   A. The function of controlling tropics to be discussed
   B. Methods to achieve balance participation by members
   C. The team leader closing sown a discussion so that decisions can be made
   D. Monitoring attendance and replacing members who have shown disinterest by not attending meeting on a regular basis

11. Which of the following statements about team meeting is the most correct?
   A. Team meetings are important, but they are not treated as high priority work
   B. Emphasis on attending meetings on time is a distracting carry-over from more formal behavioral requirements
   C. Team, meeting should start and stop on time
   D. Meetings should be extended if meaningful progress is made

12. Interpersonal problems can be solved:
   A. By establishing ground rules
   B. with a combination of ground rules and team leader actions
   C. By reminding member of their responsibilities
   D. By returning disruptive members to their own organization

13. Overbearing team members:
   A. Limit discussion and free exchange of ideas
   B. Will evaluate each idea and reject ideas that "will not work"
   C. May criticize ideas from others
   D. All of the above

14. Members with dominating personalities:
   A. Try to control team meetings
   B. Like to hear themselves talk
   C. Have no tolerance for other opinions
   D. All of the above

15. If a member is reluctant to participate, it could mean that:
   A. The member is uncomfortable in the meeting
   B. The member is distracted by personal problems
   C. May not care about team participation
   D. All of the above

16. Impatient members may be:
   A. Trying to help the team leader keep the meeting on schedule by relaxing the atmosphere
   B. Trying to push activities to achieve personal goals
   C. Able to handle information faster than other team members
   D. Trying to get more ideas exposed within the limited time

17. A negative member should be:
   A. Generally ignored and given time only for positive comments
   B. Permitted to "talk it out" and then asked to withhold all other negative comments
   C. Quickly removed from the meeting for a one-on-one discussion with the team leader
   D. Asked to listen, withhold comments, and to meet with the team leader in a future private meeting.

18. An indifferent team member:
   A. Is the same as a negative participant, and should be handled the same way
   B. Should be ignored since their attitude is disruptive
   C. May be encouraged to participate through the use of open ended questions
   D. Should be removed from the team and returned to their own organization

19. When you have team members who feud or constantly argue with one another, you should:
   A. Encourage the feuding since open conflicts are always constructive
   B. Push them to some agreement for managing their differences without disrupting the group
   C. Immediately notify higher management so that they might take action to stop the feuding
   D. Stop the meeting immediately, and get the adversaries to discuss the issues. Offer to facilitate the discussion

20. Interpersonal relationships in team environments:
    A. Become more personal by recognize differences in rank or authority
    B. Become more personal and lines of authority remain intact
    C. Are more open to public view
    D. Are built on trust and mutual respect

Table C-4
Multiple Choice Test on Leadership

1. Characteristics of a team oriented company are...
    A. Focus on functions, efficiency , emphasis on process and strong management control
    B. Profit centered, proficient operations, process control and strong leadership
    C. Employee centered, emphasis on process and consistent quality
    D. Employee centered, emphasis on process and consistent quality and customer driven

2. Teams are beneficial to employees because they:
    A. Give employees a feeling of belonging
    B. Make it easier for employees to learn from the supervisor
    C. Allow for the team members to participate in decisions; improve morale
    D. Require employees to learn new skills

3. Teams are beneficial to the company because...
    A. The company can take advantage of employee's experience and knowledge
    B. They help the image of the company and in attracting highly skilled employees
    C. They are a good marketing tool
    D. They spread out responsibility for errors

4. Participative leadership can be best characterized as:
    A. Directing teams as to specifics
    B. Managing activities of employees
    C. Coordinating team activities
    D. Solving employee's problems

5. Team leadership skills can be:
    A. Learned through experience
    B. Learned through specialized training
    C. Learned Through Specialized training and experience
    D. Passed on from father to son

6. Leadership skills can include all of the following EXCEPT:
    A. Coordination
    B. Report generation
    C. Training
    D. Dealing with interpersonal relationships

7. Which of the following statements concerning leadership styles is true?
    A. Transition to a team leadership style takes time and effort
    B. The supervisory leadership style takes time and effort
    C. Leadership is learned only through specialized training
    D. Passed on from father to son

8. A team leader will periodically hold meetings. When meeting, a good leader will:
    A. Make sure the room is set up like a classroom in order to make presentations easier
    B. Mentally develop and keep an agenda to follow
    C. Encourage participation by requiring everyone to take notes
    D. Be concerned about the meeting room environment

9. Decisions should be made by:
    A. Experts in planning and engineering organizations
    B. Team leaders in conjunction with technical notes and experts from engineering
    C. Team members on the floor, based on their expertise
    D. By the team only when forced to do so by management

10. Consensus building means that:
   A. You agree to go along this time if the group will agree with you next time
   B. Everyone agrees to support the selected solution alternative
   C. More than a simple majority is needed to make the decision but not everyone needs to agree
   D. Selected alternatives should reflect guidance received from management

11. The primary concept in team decision making is to:
   A. Make the best decision possible in the shortest time and go back to work - no one will remember where the solution came from if it turns out to be wrong
   B. Make maximum use of past experience and stay away from new or innovative ideas - there is too much risk
   C. Generate ideas, evaluate the ideas and then select the best alternative
   D. Generate ideas, form recommendations and then forward to management for a decision

12. Team meetings should be held:
   A. Periodically to remind members that they belong to a team
   B. Whenever or as frequently as management will provide the time form the job
   C. When there is a need - it has a purpose - and will not become a social period
   D. When the team leader is being pressed by management and he needs more hands to prepare something for them

13. The following is an example of a closed ended question.
   A. John, what are your thoughts about Peter's suggestion?
   B. How would you improve the process
   C. Do you think that this is the best way?
   D. Why do you think that this will work?

14. Constructive feedback is:
   A. Listening and focusing your attention on the speaker
   B. Drawing out the speaker by challenging his comments or by asking the sources of the information being furnished
   C. Providing positive comments (feedback) - turning mistakes and error into learning experiences.
   D. Telling workers how to do a task correctly to make them more efficient

15. Which of the following statements concerning feedback in general is correct?
   A. Give both positive and negative feedback.
   B. Constructive feedback should emphasize the negative and should be given to redirect and/or improve performance.
   C. Avoid negative feedback since it lowers self-esteem and reduces team performance.
   D. New team teaching techniques encourage the elimination of negative feedback - provide only positive feedback.

16. To get your message across to team members:
   A. Plan to tell them the main point at least three different ways and then summarize.
   B. Keep your message concise - use simple language - and check for understanding.
   C. Make a concise statement - they are smart and do not need repeated explanations.
   D. Make a short statement and open discussions for clarifying questions.

17. Should you always check discussions for understanding?
   A. No - you don't want to insult team members or imply that they are slow learners.
   B. Yes - it will help ensure that there is a common understanding.
   C. No - give team members a chance to follow instructions - if mistakes are made, use the learning experience - if no mistakes are made, it will build confidence.
   D. Yes - it will give team members time to think about what was said and make the meeting more meaningful.

18. All the following are ways to encourage participation in a meeting EXCEPT:
   A. Show attentiveness with voice and facial expression
   B. Have presentations done by specialists
   C. Use open ended questions
   D. Use silence

19. As a team leader you are concerned with the training of your team members. Besides this, you:
   A. Are responsible for record keeping of training received by your team
   B. Should regularly hold written and practical tests
   C. Encourage your team members to take advantage of training that is offered
   D. Conduct certification reviews

20. A team member has a personal problem and is disrupting work. As a team leader you should:
    A. Talk to him on a one-on-one basis - let him know that you care.
    B. Trade was stories with him to make him believe that he is very lucky - his experience could have been worse.
    C. Ask him to take time off until he can solve the problem - safety may become a major problem.
    D. Ask him to leave his problems outside of the job - it is distracting - reduces productivity - may cause a safety hazard. Tell him you are interested.

6.11.4 Appendix D - Usability Questionnaires

Table D-1
General Questions

Instructions

The following statements are to be used to evaluate the training delivery system. The following seven point scale is used:

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

Contents

The amount of information presented was adequate.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

The subjects were thoroughly covered.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

The information presented was understandable.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

Mechanics

The videos were helpful in understanding the concepts presented.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

The short questions presented during instruction, were helpful in reinforcing what you learned.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

The language used by the speaker was understandable.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** **Very Strongly** Agree

Presentation format

The screens / overheads were understandable.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

The information presented flowed smoothly.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

The presentation was interesting.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Usefulness

The knowledge gained from each of the following modules was useful.

Communication module

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Decision making module

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Interpersonal relationship module

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Leadership module

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Table D-2
Usability Questionnaire for
Computer-based Training (CBT)

Instructions

The following statements are to be used to evaluate the training delivery system. The following seven point scale is used:

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

Presentation

The voice over helped in understanding the material.

1	2	3	4	5	6	7

Very Strongly Disagree **Neutral** Agree **Very Strongly**

The tutorial was easy to use.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

It was easy to navigate through the tutorial.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

Format

The colors used on the screen were pleasing.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The buttons on the screen were easy to understand.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The delays while the computer worked did not frustrate you.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

You were satisfied with the interaction with the computer.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The tutorial was effectiveness in providing instruction.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

Table D-3
Usability Questionnaire for
Instructor-based Training (IBT)

Instructions

The following statements are to be used to evaluate the training delivery system. The following seven point scale is used:

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

Presentation

The instructor was effective in presenting the material.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The presentation was interesting.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The instructor talked at an acceptable pace.

1 **2** **3** **4** **5** **6** **7**

Very Strongly **Neutral** **Very Strongly**

Disagree Agree

Format

The videos were easy to see.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The overhead projections were easy to see.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The instructor interacted well with the students.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

The instructor was easy to understand.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

I was satisfied with the effectiveness of this classroom training.

1	2	3	4	5	6	7

Very Strongly **Neutral** **Very Strongly**
Disagree Agree

6.11.5 Appendix E - Narrative of Problem for Non-routine Maintenance Task

I was flying in from Chicago, and on my way here I had flown through some bad weather. There was a storm with rain and lightening, but I was never hit by anything. There was also a lot of turbulence. As I approached the Greenville Airport, I lowered my landing gear, but the nose gear light showed that I had a failure. I panicked!! I radioed the tower of my situation, and they alerted their crash crew. As I flew by the tower, they said that the landing gears were down, but they couldn't tell if they were locked or not. I had to take a chance. It was really tense for a while, but I landed safely. An inspection of the gears showed that they were in fact locked down. I don't know what is wrong with the landing gear light, but I need it repaired within the next hour.

Suggested procedure:

1. Research
   System configuration

2. Trouble shoot
   a. Preliminary
   b. In-depth

3. Correct problem

4. Verify correction - swing gear if necessary

5. Maintenance record update

6. Clean up

6.11.6 Appendix F - Instructor's/Self Evaluation Report

Table F-1
Communication

1. Team members used proper terminology when communicating either verbally or written.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

2. Team members asked for clarification on a communication that was unclear.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

3. Team member called attention to mistake made by another team member without being negative.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

4. During a shift change, discussions were held at the location of the specified work.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

5. Team members actively listened to fellow members.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

6. Non-routine work cards were filled out properly.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

7. Overall, the team communicated effectively.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

Table F-2
Decision Making

1. The team leader solicited input from team members

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

2. As a problem was presented to the team as a whole, it was well defined so that everyone understood.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

3. When discussing a problem, all team members participated in the discussion.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

4. The team made their decisions in an effective manner.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

5. Team members carried out solutions/decisions with commitment and pride.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

6. Team members effectively used external sources of information to help make decisions.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

7. Decision making tools (i.e. brainstorming, consensus, etc.) where effectively used.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

Table F-3
Interpersonal Relationships

1. When asked for help, team members willingly and openly provided assistance.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

2. The group worked well as a team.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

3. Team members had a positive attitude about their work.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

4. Team members remained focused on their work.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

5. Team members encouraged and supported one another.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

6. Team members gave unsolicited and unnecessary advice to one another.

1 2 3 4 5 6 7

Very Strongly Disagree Neutral Very Strongly Agree

7. Team members did not relate well to one another.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

Table F-4
Leadership

1. The leader failed to verified if information he provided was understood by all recipients.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

2. The team leader accepted ideas and contributions from team members.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

3. Team leader coordinated gathering of information in an effective manner.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

4. Leader reviewed procedures and assignments with team prior to a task requiring teamwork.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

5. The team leader dealt effectively with questions asked by team members.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

6. The team leader fostered cooperation within the team

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

7. The team leader dealt effectively in inter-team cooperation/negotiation.

1	2	3	4	5	6	7

Very Strongly Disagree   Neutral   Very Strongly Agree

6.11.7 Appendix G - Scenarios Used to Create Artificial Situations

1. Shift change
   Approximately one-half hour into the RM task, the team will be told that that their work shift will end in 15 minutes. The team will need to prepare a non-routine work card to pass their work onto the next team. After the turnover, they will return to their work.

2. Loss of personnel
   fifteen minutes into the NM task, a team member will be selected at random and will be removed from the team for fifteen minutes.

3. Equipment not immediately available
   The platform scales will be withheld from the team for ten minutes. The team will have to coordinate with supplies to determine when the scales will be available.

4. Extra weight in plane
   The work cards specify that all extraneous equipment be removed from the plane before weighing. Two large piece of equipment will be placed in different part of the plane.

5. Shared equipment
   Only one tow tug is available and must be shared by the two teams as they perform their tasks.

6. Towing of aircraft
   Both planes will be located outside the hanger on the runway apron. Only one plane at a time can safely be moved into the hanger. Teams must coordinate movements.

7. Flaps down
   The flaps on both planes will be in a down position. These flaps must be brought to level before work can proceed on plane.

8. Missing work cards
   The fifth and sixth work card will not be provided to the team conducting the RM task unless they notify their supervisor (Instructor) that it is missing.

9. Interruption
   During the NM task, a visitor will stop by plane and spend five minutes asking questions about their work.

Chapter 7
CREATION OF TEAM SITUATION AWARENESS TRAINING FOR MAINTENANCE TECHNICIANS

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7.1 INTRODUCTION

Situation awareness (SA) has been found to be highly important for effective functioning in many dynamic and complex environments including that of aviation maintenance. Although largely neglected in human factors efforts, maintenance represents a very challenging area in need of efforts geared for improving human performance and reducing human error. Marx and Graeber[1] report that 12% of aircraft accidents are due to maintenance and inspection faults and around one third of all aircraft malfunctions can be attributed to maintenance deficiencies. Technicians must detect critical and often subtle cues under very challenging conditions, use this information to develop a proper assessment of the state of the system and diagnose system abnormalities, and project the impact of their actions on the future functioning of the system, all of which form their situation awareness. Failures in SA have been linked to conditions which lead to reductions in the safety of flight, flight delays, ground damage, and other problems that directly impact airline costs and business viability.

7.1.1 Situation Awareness

These problems have led to an interest in improving SA in aviation maintenance. While SA has generally been discussed in terms of the operation of a dynamic system, such as an aircraft, the concept is also applicable to the maintenance domain. Maintenance crews need additional support/training in ascertaining the current state of the aircraft system (supplementing current technical training programs). As shown in Figure 7.1, one's assessment of the existing situation is the driving factor on which effective decision making and performance are based. Even in highly proceduralized environments, such as aircraft maintenance, the proper procedures can not be put into place unless the situation is correctly understood. Formally defined, "situation awareness is the detection of the elements in the environment within a volume of space and time, the comprehension of their meaning, and the projection of their status in the near future."[2] *This definition can be broken down to describe SA at each of three levels.*

In the context of aircraft maintenance, Level 1 SA, the perception of the elements in the environment, means being aware of the state of the aircraft system (and the subsystem on which one is working). This usually occurs by visual observation or communication with other team members. While this might seem straightforward, the complexity of aircraft systems and the distributed nature of equipment and system components posses a significant challenge to the technicians' ability to determine the state of the system during diagnosis and repair activities. Failures in this process obviously can lead to serious problems. Several accidents have been traced to metal fatigue or loose and missing bolts that should have been visible to maintenance crews. Incidents exist of aircraft being returned to service with missing parts or incomplete repairs. Frequent errors include loose objects left in aircraft, fuel and oil caps missing or loose, panels and other parts not secured, and pins not removed.[1] In all of these cases the state of the system was not detected prior to returning the aircraft to service, thus Level 1 SA was deficient.

In addition, SA involves more than merely perceiving relevant information. Level 2 SA involves the technicians' understanding or comprehension of the significance of observed system states. Putting together observed cues to form a proper understanding of the underlying nature of malfunctions is a significant problem in diagnostic activities. For instance, Ruffner[3] found that in more than 60% of cases the incorrect avionics system is replaced in an aircraft. While not much data exists regarding the impact of misdiagnoses of this type, there is a significant increase in the probability of an incident occurring when the aircraft undertakes the next flight with the faulty system still aboard. Technicians must have a sufficient understanding of the system they are working on to properly understanding the impact or significance of perceived cues.

Level 3 SA, the ability to project the state of the system in the near future, is considered the highest level of SA in dynamic systems. In the maintenance domain, technicians may need to be able to project what will happen to an aircraft's performance with (or without) certain actions being taken or with given equipment modifications/repairs/adjustments occurring. This task may be even more difficult for maintenance technicians, as they often receive little or no feedback on the effects of their actions. Thus, they may have difficulty developing an adequate mental model for making accurate predictions. The ability to project system status forward (to determine possible future occurrences) may also be related intimately to the ability to project system status backward, to determine what events may have led to an observed system state. This ability is particularly critical to effective diagnostic behavior. Making projections in regard to scheduling and forecasting activities also forms a critical component of aircraft maintenance activities.

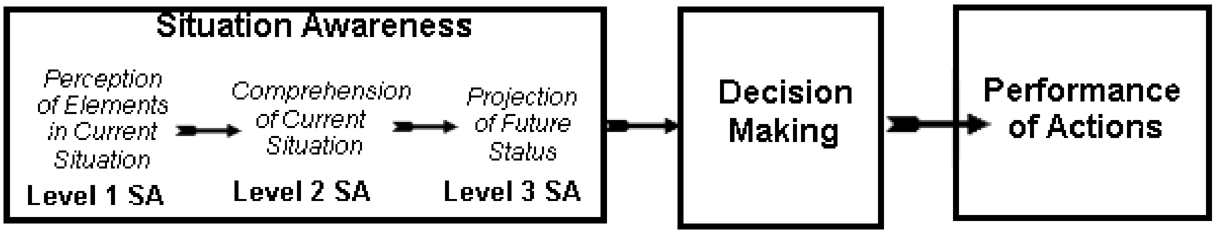

Figure 7.1 Role of Situation Awareness in Task Performance

7.1.2 SA in Multiple, Distributed Teams

The ability to develop an accurate ongoing picture of the situation is compounded by the fact that many different individuals may be involved in working on the same aircraft. In this situation, it is very easy for information and tasks to fall through the cracks. The presence of multiple individuals heightens the need for a clear understanding of responsibilities and communications between individuals to support the requirements of individuals in performing those tasks. In addition to the need for intra-team coordination, a significant task befalling maintenance crews is the coordination of tasks and information across teams, to those on different shifts or in different geographical locations. The Eastern Airlines incident at Miami Airport4 has been directly linked to a problem with coordination of information across shifts (along with other contributing factors). In addition, considerable energy is often directed at coordination across sites to accommodate maintenance tasks within flight schedule and parts availability constraints. These factors add a level of complexity to the problem that increases the probability of tasks not being completed, or completed properly, important information not being communicated, and problems going undetected as responsibility for tasks becomes diluted.

In aircraft maintenance, as in many other domains, the requirement for situation awareness becomes compounded by the presence of multiple team members and multiple teams. Individuals not only need to understand the status of the system they are working on, but also what other individuals or teams are (and are not) doing. Both factors contribute to their ultimate decision making and performance. Team situation awareness can be defined as "the degree to which every team member possesses the situation awareness required for his or her responsibilities."5 In this context, the weak link in the chain occurs when the person who needs a given piece of information (per his or her job requirements) does not have it. The level of SA across the team, therefore, becomes an issue of some concern. If any individual within the team does not have the SA he or she needs, the overall goal (a safe aircraft) can be compromised. Therefore, trying to insure that everyone within the maintenance team has the SA required for his or her job is paramount.

The degree to which team members possess a shared understanding of the situation with regard to their shared SA requirements is an extremely important aspect of team SA. Shared SA can be defined as "the degree to which team members possess the same SA on shared SA requirements." Shared SA can be depicted as the shaded area in Figure 7.2, where each circle represents the SA requirements of each team member. It is the area where these requirements overlap that constitutes the need for a shared understanding of the situation within a team. Similarly, where the SA requirements overlap between teams, a shared understanding of this information is equally important to enable teams to achieve their maintenance goals.

Developing shared SA within a team and between teams can be extremely challenging, especially where those teams are distributed in terms of space, time, or physical barriers. This has been described as a function of four components.6

(1) Shared SA Requirements - the degree to which the team members know which information needs to be shared, including their higher level assessments and projections (which are not usually otherwise available to fellow team members), and information on team members' task status and current capabilities.

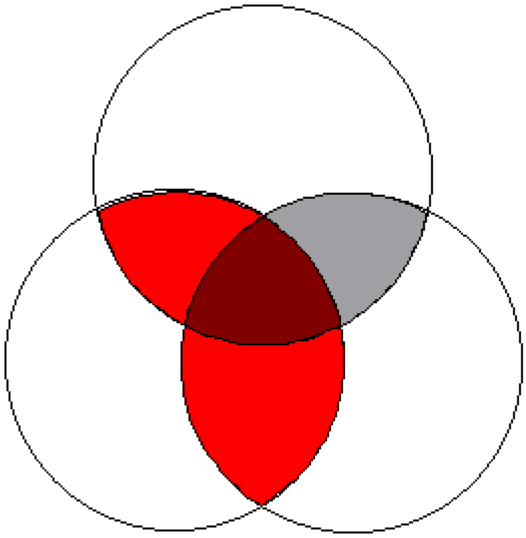

Figure 7.2 Shared SA Requirements

(2) Shared SA Devices - the devices available for sharing this information, which can include direct communication (both verbal and nonverbal), shared displays or a shared environment. As nonverbal communication and a shared environment usually are not available in distributed teams, this places far more emphasis on verbal communication and technologies for creating shared information displays.

(3) Shared SA Mechanisms - the degree to which team members possess mechanisms, such as shared mental models, which support their ability to interpret information in the same way and make accurate projections regarding each other's actions. The possession of shared mental models can greatly facilitate communication and coordination in team settings.

(4) Shared SA Processes - the degree to which team members engage in effective processes for sharing SA information. This may include a group norm of questioning assumptions, checking each other for conflicting information or perceptions, setting up coordination and prioritization of tasks, and establishing contingency planning among others.

Team SA has been investigated in aircraft maintenance.[7] Several teams were identified within the aviation maintenance setting, each of which involved leads and supervisors as well as line personnel (aircraft maintenance technicians [AMT], stores, maintenance control, maintenance operations control, aircraft-on-ground, inspection, and planning). A delineation of situation awareness requirements for each of these groups and an understanding of the way in which each group interacts with the others to achieve SA pertinent to their specific goals has been determined. These SA requirements appear to be crucial to the ability of each group to perform tasks (as each task is interdependent on other tasks being performed by other team members), their ability to make correct assessments (e.g., whether a detected problem should be fixed now or later [placarded]), and their ability to correctly project into the future to make good decisions (e.g., time required to perform task, availability of parts, etc.). Shortcomings, both in the technologies employed and in the supporting organizational/personnel system were identified that may compromise Team SA in aircraft maintenance. Five key concepts for improving Team SA through training were identified for the supporting organizational/personnel system: (1) shared mental models, (2) verbalization of decisions, (3) better shift meetings and teamwork, (4) feedback, and (5) SA training.

The objective of the current effort was to develop these Team SA training concepts into a deliverable training program and to make a preliminary assessment of the program based on a prototype implementation.

7.2 TRAINING RECOMMENDATIONS

Five training concepts were identified and developed for improving Team SA within the aircraft maintenance setting.

7.2.1 Shared Mental Models

It was determined that different teams (organizations) do not have a good mental model of what other teams know, do not know, or need to know. Good situation awareness at the team level depends on having a clear understanding of what information means when it is conveyed across team members. Teams need to share not only data but also higher levels of SA, including the significance of data for team goals and projection information. This process is greatly enhanced by the creation of a shared mental model which provides a common frame of reference for team member actions and allows team members to predict each other's behaviors. A shared mental model may provide more efficient communications by providing a common means of interpreting and predicting actions based on limited information, and, therefore, may form a crucial foundation for effective teamwork. When shared mental models are not present, one team may not fully understand the implications of information transmitted from another team and misunderstandings, errors, and inefficiencies are likely to occur. By providing each team with better information on the goals of other teams, how they perform their tasks, and what factors they take into account in their decision processes, a better shared model can be developed. This should greatly enhance not only interpersonal interactions among teams, but also the quality of the decision processes.

7.2.2 Verbalization of Decisions

There also exists a need for teams to do a better job of passing information to other teams regarding why they decide to (or not to) take a particular course of action (e.g., deferments, schedules, etc.). Unless the rationale and reasons are passed along, considerable misunderstandings may occur. In addition, this will deny the possibility of getting better information from the other team, who may have access to other pertinent information that would make for a more optimal solution. Conveying why a particular decision was made provides a much greater level of SA (particularly at the comprehension level). It allows other teams to either understand and accept the decision or to offer other solutions that may be better in achieving organizational goals. More information also needs to get conveyed on what diagnostic activities have been performed when passing aircraft to another station, and a need exists for better communications between stations and teams in general. Training that focuses on teaching people to verbalize the rationale behind decisions and provide greater detail regarding diagnostic activities should help improve Team SA considerably.

7.2.3 Better Shift Meetings and Teamwork

Team leads need to receive explicit training on how to (1) run a shift meeting to convey common goals for the team, (2) provide a common group understanding of who is doing what, (3) set up an understanding of the inter-relationship between tasks and personnel activities, and (4) provide expectations regarding teamwork. Shift meetings provide an excellent opportunity to provide this shared understanding among the members of a team. This information is crucial for allowing team members to have a good mental model regarding what everyone is doing and how tasks interrelate so that they can have good SA regarding the impact of their actions and tasks on other personnel and on the overall goal. Team leads also need to receive specific training on the importance of passing information on job status within teams over the course of the shift. Without this type of feedback, people can easily lose sight of how they are progressing in relation to the other tasks being performed. This feedback is important for individual performance and SA, and also for fostering a team spirit in carrying out activities.

7.2.4 Feedback

Currently, personnel receive little feedback on how well a particular solution worked. A tricky diagnosis and repair may have been totally successful, or may have failed again a few days later at another station. At present, it is very difficult to track the performance of a particular action or part (partially due to the cumbersome nature of the computer system). Such feedback is crucial to the development of better mental models of the technical systems technicians work on. Without such feedback, it is very difficult to improve one's diagnostic skills. While system enhancements are recommended to help with this problem, it is also recommended that people be trained to provide such feedback. Not only do managers and leads need to take an active role in providing this feedback, but also technicians (and others) can be trained to provide more feedback (either over the phone or through the computer system) on what worked and what did not.

7.2.5 SA Training

Common problems can be linked to SA failures in a number of systems, including (1) forgetting information or steps, frequently in association with task interruptions, (2) not passing information between shifts or team members, (3) missing critical information due to other task-related distractions, and (4) misinterpreting information due to expectations. Training can be used to provide heightened awareness of these problems and ways of combating them. For instance, task interruptions are a common problem leading to SA errors. Frequently such interruptions lead to skipping steps or missing activities. Personnel can be trained to take particular measures following a task interruption (double check previous work performed, double check area for loose tools, etc.). This type of training may be useful for helping maintenance personnel to insure that they are not missing critical information in the performance of their tasks.

7.3 TEAM SA TRAINING PROGRAM

The instructional design methodology that was used in designing and developing the Team SA training program involved a systematic approach incorporating an instructional systems design model. This included a front end analysis and needs assessment of team members' performance requirements; analysis, design, and development of the instructional goals, objectives, functional design requirements and specifications; and selection of media and delivery mechanisms. The final step of the instructional systems design model includes instructional prototyping, user testing, and formative and summative evaluations. This instructional design processes is iterative in nature. After the initial instructional program design and prototype, feedback on performance changes is collected and changes in the instructional systems environment occurs. There should be a ongoing validation effort to insure that the initial training goals, objectives and needs analyses are being fulfilled by the instructional program.

The first two phases of the instructional systems design approach have been completed -- the front end analysis and the design and development of a team SA training program. The results from the SA resource analysis for aviation maintenance8 served as the front end analysis for the training program including an organizational analysis, task or job functional analysis, and trainee analysis. For the second phase of the instructional design model, the specific training goals, objectives, instructional sequence, instructional strategies and delivery mechanisms or methods (media selection) of the training program were determined and completed, resulting in an instructional design document and deliverable training program.

7.3.1 Instructional Design Process

From the results of the SA Resource Analysis,8 the instructional objectives and goals were determined. The five team SA training concepts that were specified from the analysis determined the performance requirements and learning outcomes that the SA training program must accomplish. These instructional goals and objectives are specified in the learning task hierarchy shown in Figure 7.3. The terminal objective for the team SA training program is stated at the top of the hierarchical figure with each of the enabling training objectives leading to the terminal objective listed below. The flow of the learning task hierarchy is from the bottom to the top where the successful accomplishment and learning of one training objective is necessary before moving to the next higher level training objective. The trainee's prior knowledge analysis is depicted at the bottom of the task learning hierarchy which specifies the skills, abilities, and knowledge that the trainees have prior to entering this training program. Thus, the learning task hierarchy builds on these skills, abilities, and knowledge level in order to accomplish the stated enabling training above.

Trainees are expected to have acquired certain skills in listening, communication, assertiveness, stress management and leadership from a prior course in maintenance resource management. Building on this knowledge, the concept of situation awareness and mental models are introduced at the individual and team level. To develop shared mental models across maintenance teams, the next objective is to develop an understanding of the goals, processes and SA requirements of other teams in aviation maintenance. The next training objective is to develop skills relating to verbalization, including how and why to verbalize the reason for decisions and actions when interacting with other team members or other teams. Following this, the next objective is to develop skills at the level of the team which include those related to keeping up with what other team members are doing, how tasks are interrelated and common expectations regarding teamwork. The importance of feedback on developing diagnostic skills in maintenance tasks is then stressed, with emphasis on creating mechanisms for getting and providing feedback within the system. Finally the effects of numerous factors which can lead to SA errors in aviation maintenance are addressed with the objective that trainees be able to identify such factors and plan for them. In total, the accomplishment of these objectives will lead to the overall training objective which is to equip technical operations personnel with the skills and abilities to develop an awareness and understanding of factors that affect SA in the maintenance domain and team processes that can enhance SA in this environment.

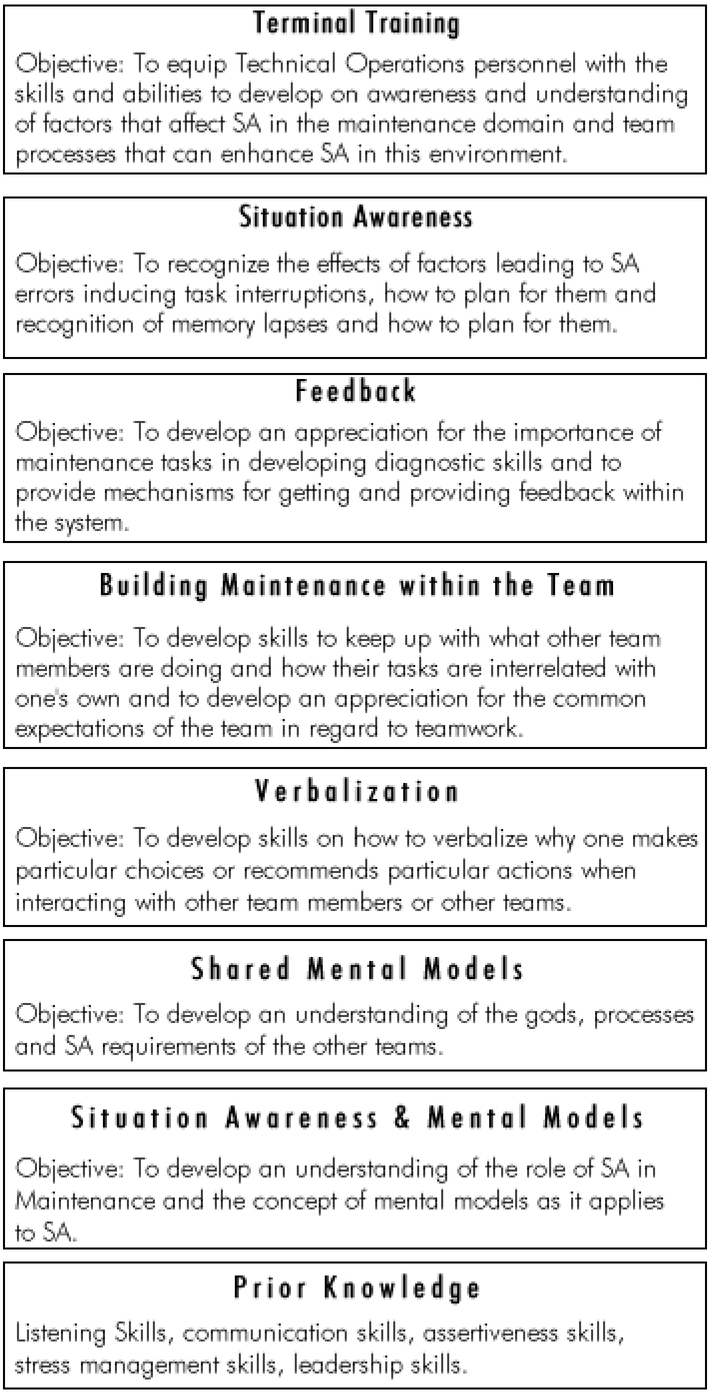

Figure 7.3 Learning Task Hierarchy

7.3.2 Instructional Development Process

The instructional design stage for the Team SA training course has been completed resulting in an instructional design document. This document provided an overall instructional curriculum map of exactly what is accomplished in the training course in conjunction with the training objectives and the resultant learning outcomes. At each level of the learning task hierarchy, the specific learning exercises, activity and delivery mechanisms were determined. Matching the training methodology or strategy, media selection and delivery mechanism with each training objective formed a critical component of this task. After the specific presentation of the each of the defined skills, knowledge or ability, the training course includes rehearsal of the newly acquired skill, knowledge or ability. The determination of what type of training activity and media presentation to include in the program was driven by the identified training objectives. Thus, the instructional sequence and presentation of the training course was aligned with the learning task hierarchy to insure a systematic approach to the training and successful accomplishment of the skill, knowledge or ability by the trainee. In keeping with inquiry and discovery learning models that have been found to be appropriate for adult learning, the course is built around an active workshop format utilizing high involvement and student participation. Group exercises involving problem solving, case studies, and role playing scenarios all within the aviation maintenance domain have been emphasized. Multimedia presentations using Powerpoint slides, videos, written case studies, and a course handbook are utilized as delivery mechanisms for the course. Section 7.7 presents the training slides used for the course, which is a result of the instructional curriculum map. A copy of the Powerpoint slide presentation, case studies, and facilitator's handbook are available on disk through the FAA Office of Aviation Medicine.

7.4 IMPLEMENTATION PROCESS

7.4.1 Strategy

The Team SA training course was designed to be presented as an eight-hour classroom delivery course. The agenda includes material on Human Factors and Maintenance Resource Management (MRM) as a review prior to the introduction of the Team SA material. The human factors and MRM skills, knowledge and abilities that are taught are considered to be prior knowledge requirements for the trainees for the Team SA workshop. These are indicated on the learning task hierarchy (Figure 7.3). In addition to a review of these principles, one group exercise is provided. Depending on the trainees' existing level of knowledge (which will be based on whether they attended a previous eight-hour or sixteen-hour MRM course), this review could be reduced or shortened. Some of the MRM review material may be new to the audience, depending on the previously presented MRM course curriculum content. The core Team SA curriculum should stay intact, however, because the instructional sequence and learning hierarchy have been carefully designed to build on previously learned SA skills and knowledge. The one exception to this is the material on conducting better shift meetings which is more attuned to an audience of leads or supervisors. Some of this material may be modified for a different audience. However, even nonsupervisory personnel need to learn the importance of gaining a shared mental model through the shift meeting.

The course is designed to be presented to personnel from across maintenance operations (also called technical operations in some airlines). The course is best taught to a class composed of a mixed cross section from different maintenance operations organizations (e.g., stores, AMTs, inspectors, maintenance operations control, etc.). This is because the course focuses on helping to reduce the gaps and miscommunications that can occur between these different groups. Much of the course's benefit will come from the interaction that will occur when they share different viewpoints and information in going through the exercises.

7.4.2 Delivery Mechanisms and Facilitators

The Team SA course should be delivered by two co-facilitators who are AMTs with facilitation experience. Co-facilitators who have previously taught MRM courses would be better qualified. They would have the MRM background and knowledge and would be comfortable in relating the previously learned material to the current Team SA course. Maintenance operations examples of the SA principles have been provided in the training course. Specific SA related examples from the airline company itself should also be incorporated into the training course. For instance, specific examples illustrating the definition of SA and encompassing the three levels of SA could be developed. Additionally, examples of how shared mental models are developed in maintenance settings should be integrated into the course. AMTs delivering this course would have the background and skills to develop examples illustrating the SA principles, especially examples that would be intrinsic to the airline company. The Eagle Lake case study that is presented at the end of the course can also serve as a review of all MRM principles in addition to the team SA information provided.

The physical layout of the room in which the course is taught should include several tables large enough to accommodate four to six trainees each. Each table should be positioned so that it provides a reasonable visual angle to the front of the classroom. This type of classroom arrangement will support group exercises and individual participation. Media requirements for this course include: an overhead projector or computer LCD projector to display Powerpoint slides, VCR, flip-charts and pens, and name tags for participants.

7.5 CONCLUSIONS

A prototype course for training SA and Team SA in the aviation maintenance domain was developed. These skills are extremely important for reducing error in aviation maintenance and improving the efficiency of the organization. It is recommended that this training program be further refined by field testing the program with aircraft maintenance personnel in order to test its effectiveness at improving SA in aircraft maintenance. Systematic gathering of feedback and initial responses from the trainees can be used to modify the training course, if necessary, to assure that the instructional objectives of the program are met and the performance requirements of the trainees enhanced.

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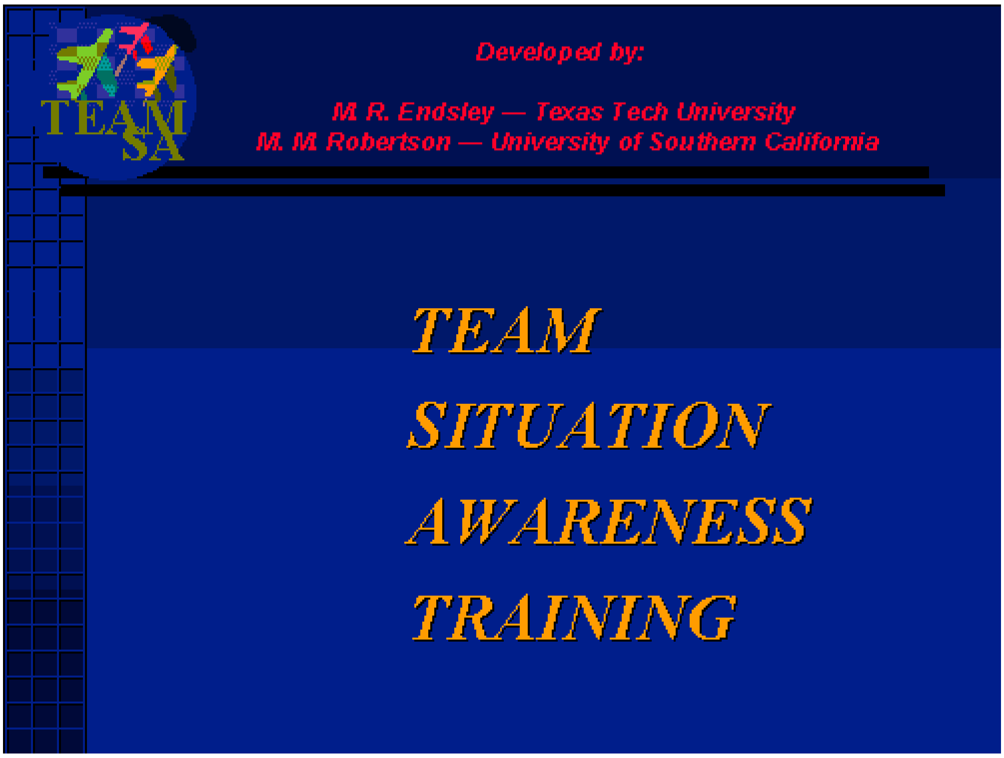
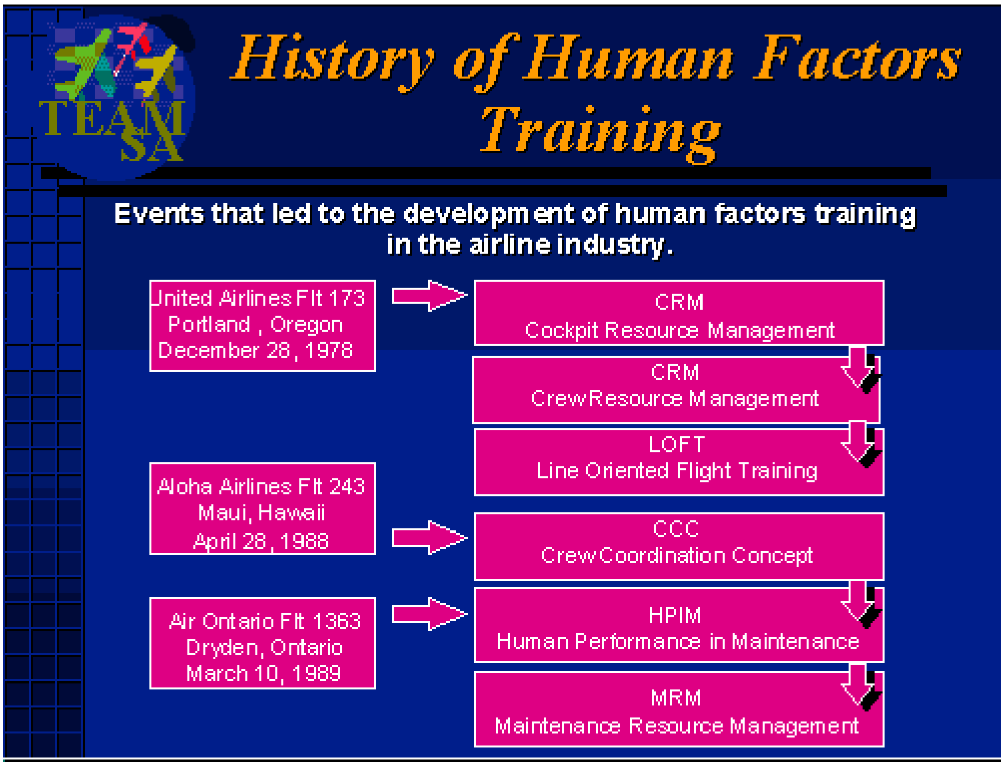
7.7 APPENDIX: TEAM SA TRAINING PROGRAM



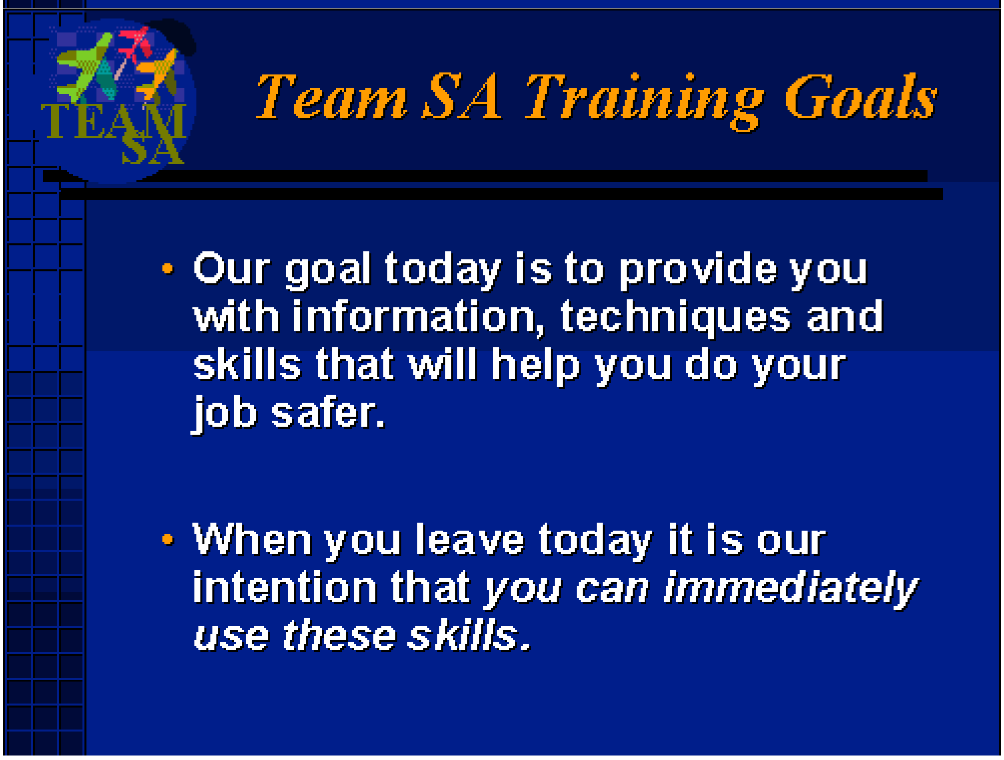

TEAM SA
Workshop Agenda
Introduction: training goals
Review of MRM concepts
What is situation awareness?
Overcoming information gaps between maintenance operations groups
Communication between teams
Teamwork and shift meetings
Use of feedback
Case study of SA in aviation maintenance

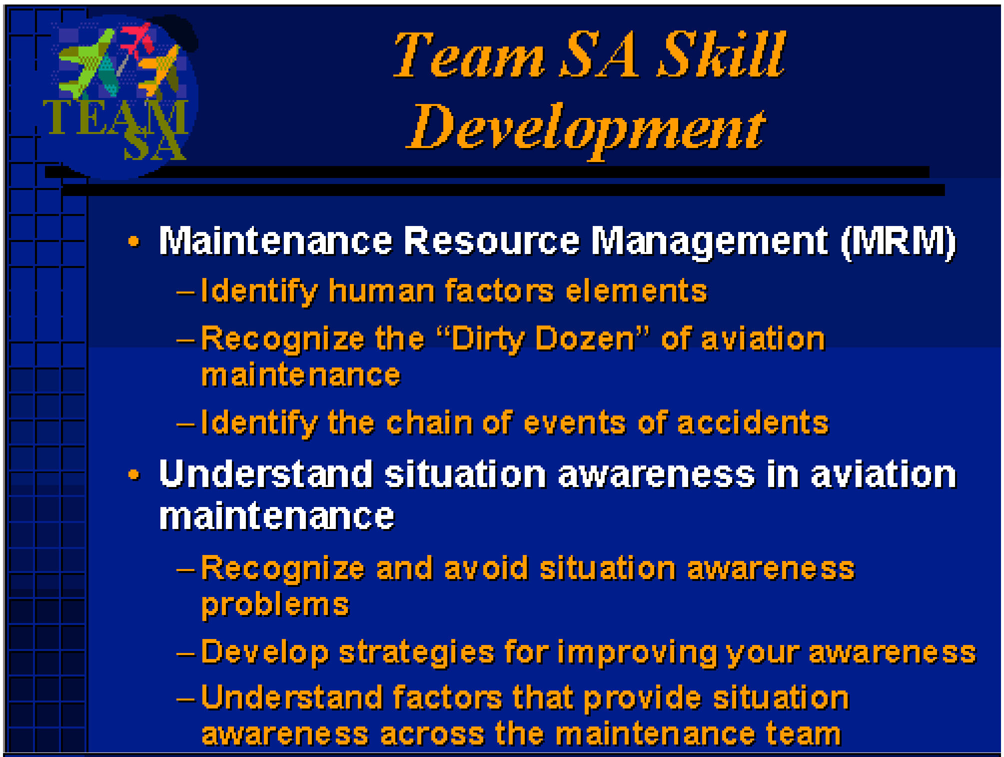

TEAM SA
Introduction
Welcome course participants
–What is your name and job description?
–How did you get into aviation?
–How many years have you been in aviation?

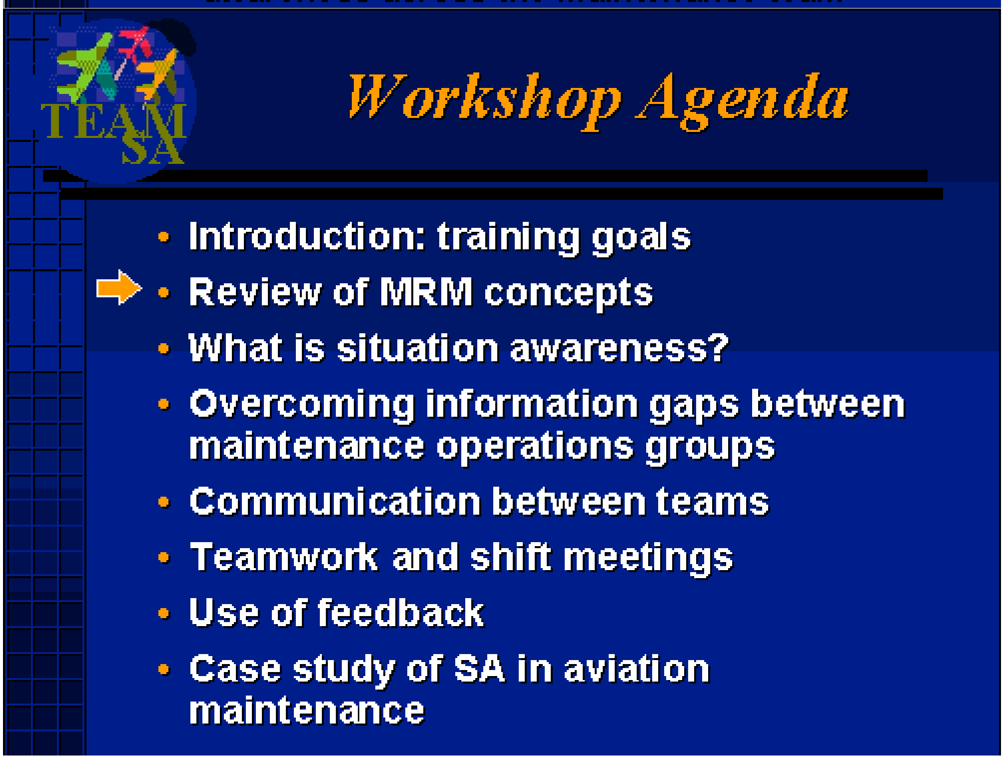

TEAM SA
History of Human Factors Training
Events that led to the development of human factors training in the airline industry.
United Airlines Flt 173
Portland, Oregon
December 28, 1978
CRM
Cockpit Resource Management
CRM
Crew Resource Management
LOFT
Line Oriented Flight Training
Aloha Airlines Flt 243
Maui, Hawaii
April 28, 1988
CCC
Crew Coordination Concept
Air Ontario Flt 1363
Dryden, Ontario
March 10, 1989
HPIM
Human Performance in Maintenance
MRM
Maintenance Resource Management


TEAM SA
Learning Approach
• Tell me and I forget
• Show me and I remember
• Involve me and I understand


TEAM SA
Training Agreement
• WE agree to:
– Act as facilitators
– Provide structure
– Direct activities
– Answer questions
– Confront issues
– Stay focused on the topic
• YOU Agree to:
– Actively participate
– Share experiences
– Be open
– Feel free to disagree
– Stay focused on the topic

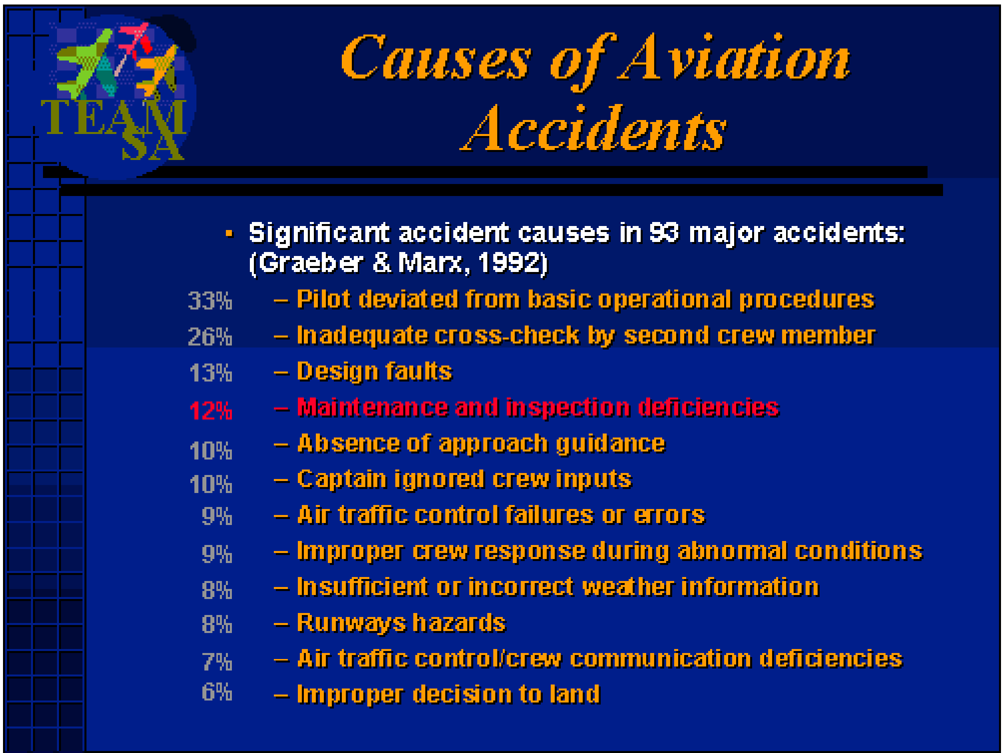

TEAM SA
Team SA Training Goals
• Our goal today is to provide you with information, techniques and skills that will help you do your job safer.
• When you leave today it is our intention that *you can immediately use these skills.*

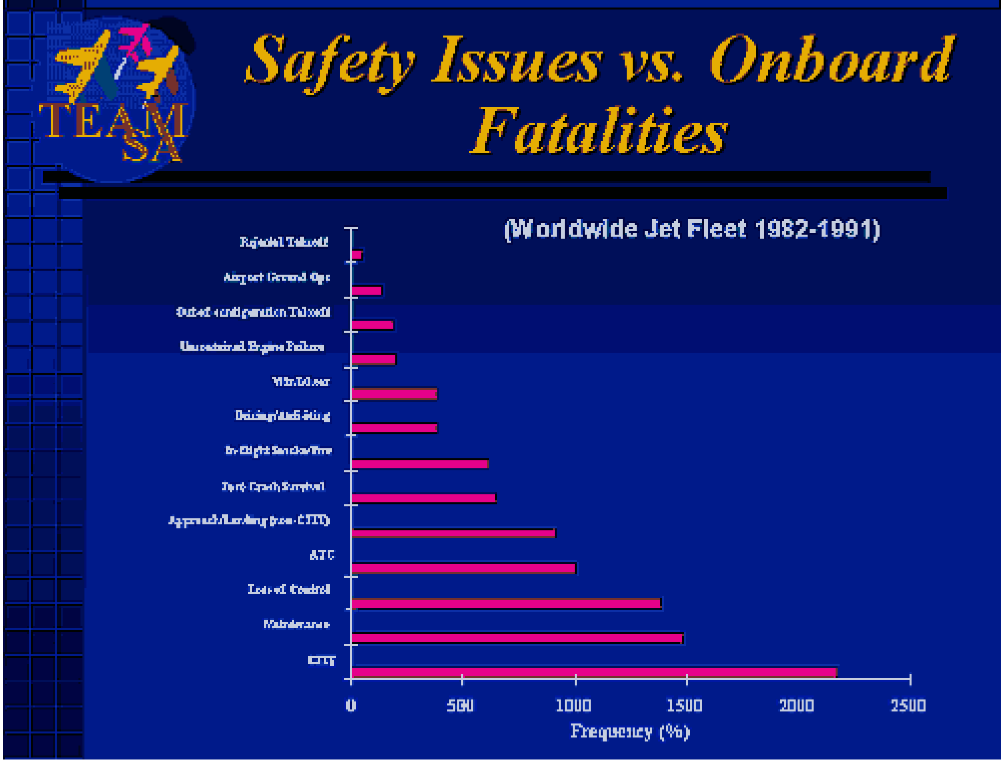

TEAM SA
Team SA Skill Development
• Maintenance Resource Management (MRM)
– Identify human factors elements
– Recognize the "Dirty Dozen" of aviation maintenance
– Identify the chain of events of accidents
• Understand situation awareness in aviation maintenance
– Recognize and avoid situation awareness problems
– Develop strategies for improving your awareness
– Understand factors that provide situation awareness across the maintenance team

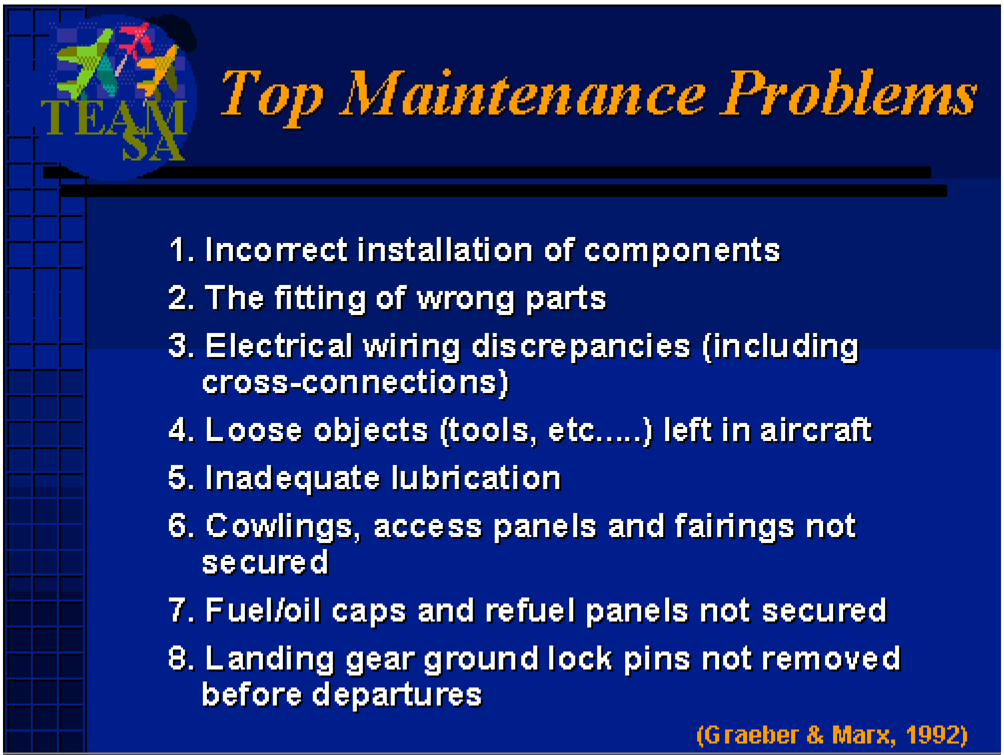

TEAM SA
Workshop Agenda
• Introduction: training goals
• Review of MRM concepts
• What is situation awareness?
• Overcoming information gaps between maintenance operations groups
• Communication between teams
• Teamwork and shift meetings
• Use of feedback
• Case study of SA in aviation maintenance

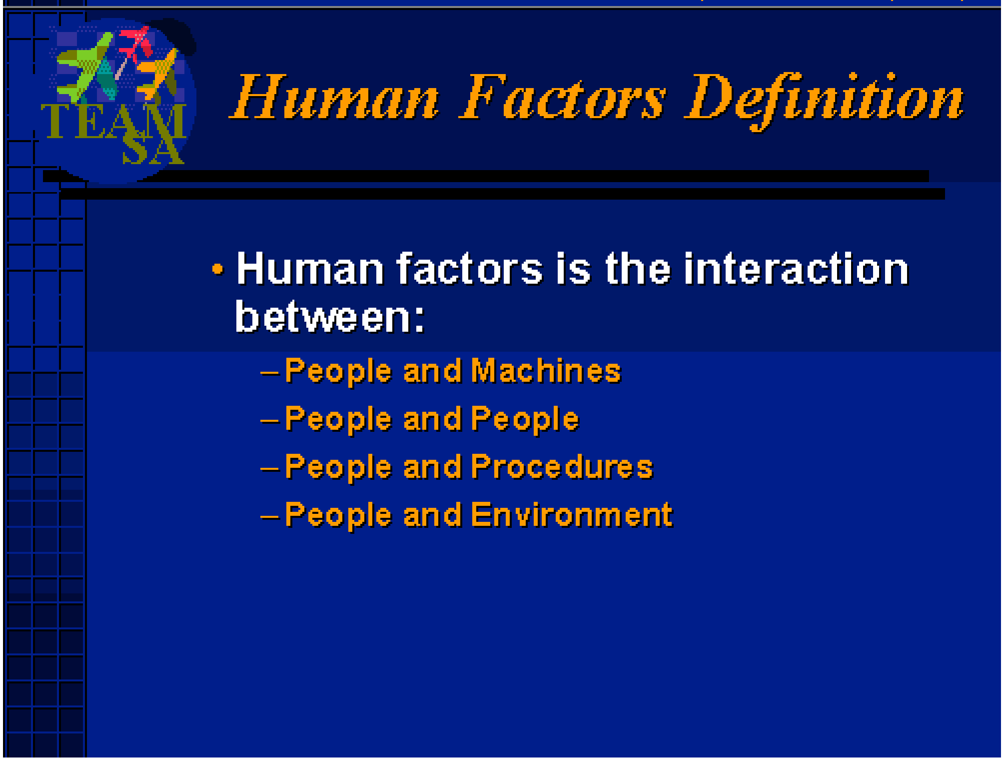

TEAM SA
Maintenance Resource Management (MRM)
• MRM addresses human factors errors and problem resolution through open and honest communication among technicians, managers, and FAA.
• MRM is working together and using available resources to reduce errors and to promote safety.


TEAM SA
MRM Goals
• This course will build on the previous skills and knowledge presented in MRM
• Enhanced teamwork
• Increase awareness
• Develop safety nets
• Increase safety
• Reduce human error

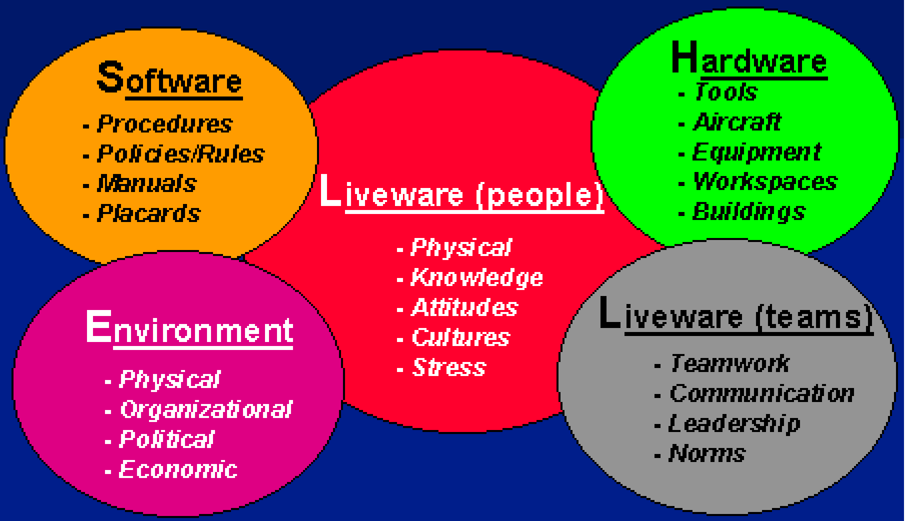

TEAM SA
Causes of Aviation Accidents
• Significant accident causes in 93 major accidents: (Graeber & Marx, 1992)
33% – Pilot deviated from basic operational procedures
26% – Inadequate cross-check by second crew member
13% – Design faults
12% – Maintenance and inspection deficiencies
10% – Absence of approach guidance
10% – Captain ignored crew inputs
9% – Air traffic control failures or errors
9% – Improper crew response during abnormal conditions
8% – Insufficient or incorrect weather information
8% – Runways hazards
7% – Air traffic control/crew communication deficiencies
6% – Improper decision to land


TEAM SA
Safety Issues vs. Onboard Fatalities
(Worldwide Jet Fleet 1982-1991)
Rejected Takeoff
Airport Ground Ops
Out of configuration Takeoff
Uncontained Engine Failure
Windshear
Deicing/Anti-Icing
In-flight Smoke/Fire
Post Crash Survival
Approach/Landing (non-CFIT)
ATC
Loss of Control
Maintenance
CFIT
0
500
1000
1500
2000
2500
Frequency (%)


TEAM SA
Top Maintenance Problems
1. Incorrect installation of components
2. The fitting of wrong parts
3. Electrical wiring discrepancies (including cross-connections)
4. Loose objects (tools, etc.....) left in aircraft
5. Inadequate lubrication
6. Cowlings, access panels and fairings not secured
7. Fuel/oil caps and refuel panels not secured
8. Landing gear ground lock pins not removed before departures
(Graeber & Marx, 1992)

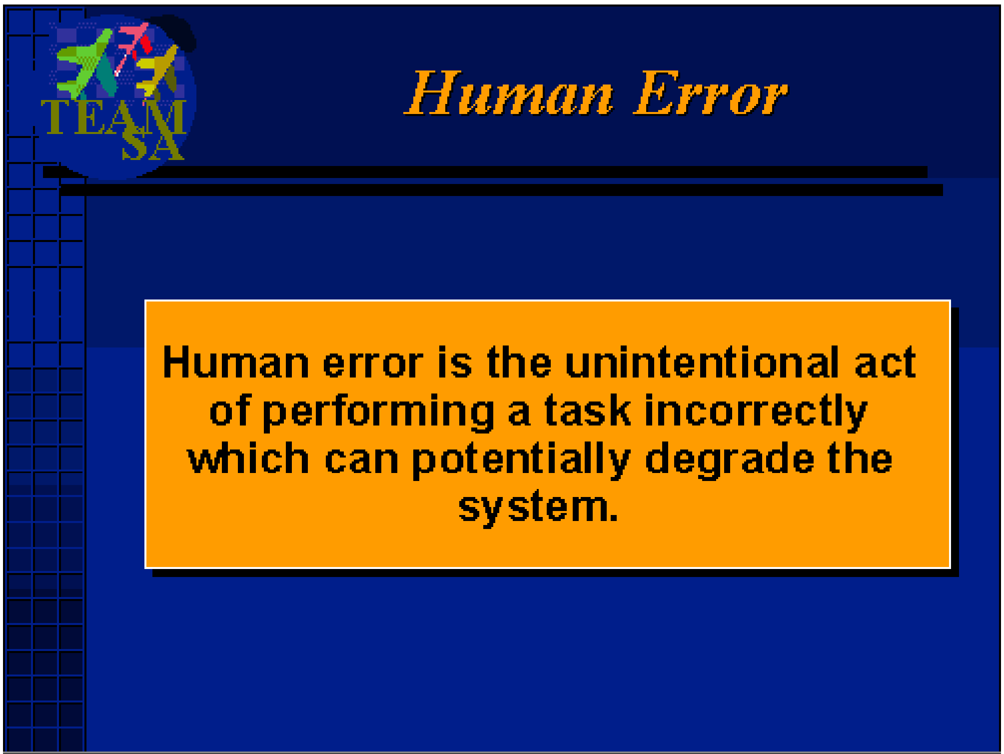

TEAM SA
Human Factors Definition
• Human factors is the interaction between:
– People and Machines
– People and People
– People and Procedures
– People and Environment

SHELL Model

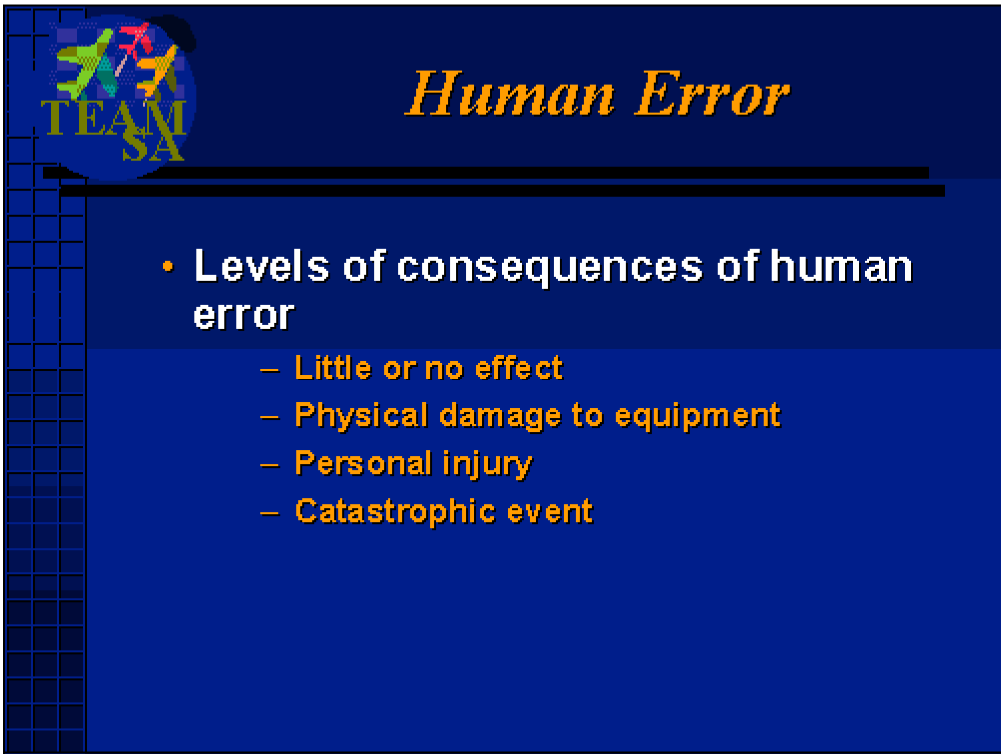


Human Factors

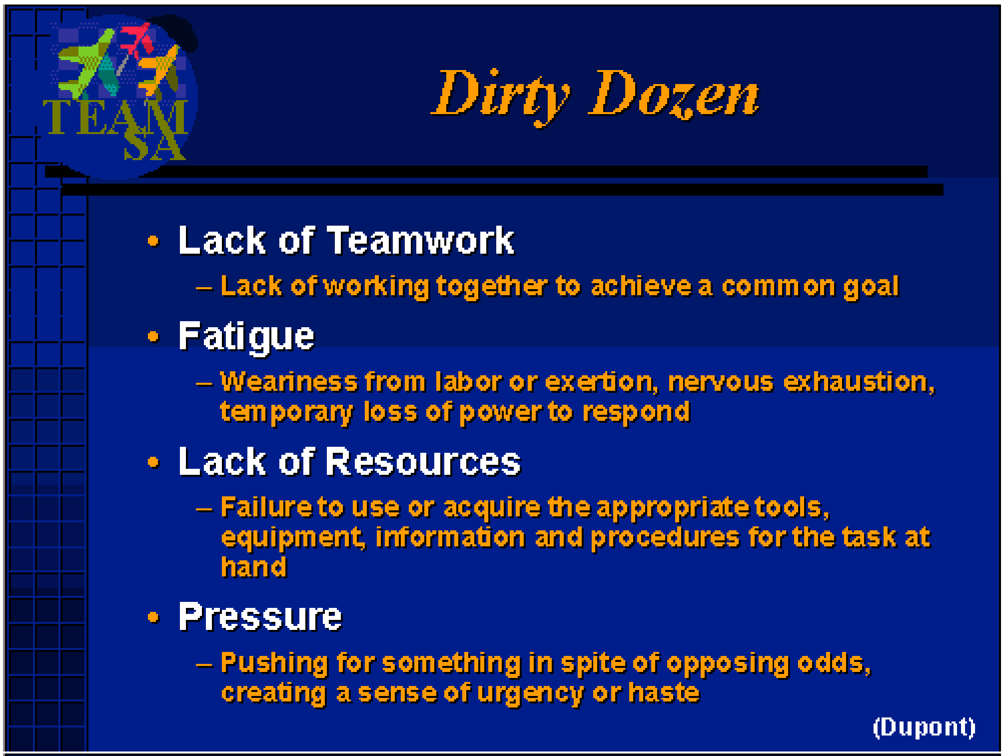
- Our performance is impacted by:
  - Design of tools, equipment (manufacturing, computers) and workplaces (hangars, offices, warehouses)
  - Design of training programs and personnel selection
  - Design of software and procedures/manuals (GMM, workcards)
  - Job Design (shiftwork, schedules and job tasks)
  - Design of the organizational environment (structure, departments, teams , decision making)
  - Physical environment factors (weather, noise, light)
  - Physical body size and dimensions.

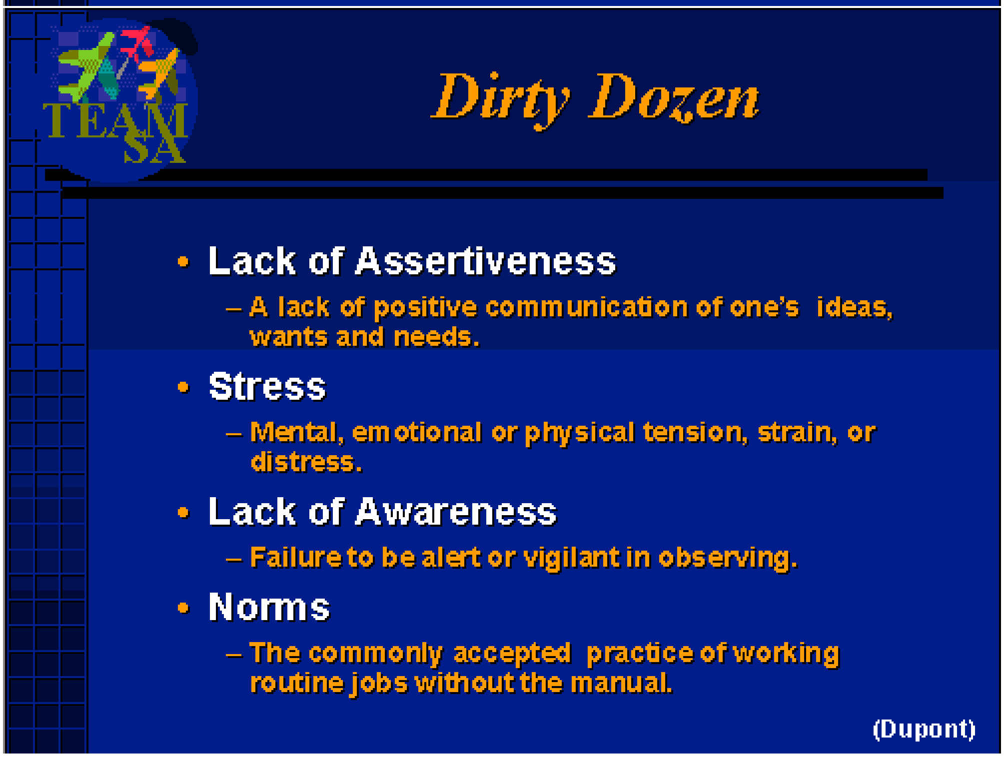

TEAM SA
Human Error
Human error is the unintentional act of performing a task incorrectly which can potentially degrade the system.


TEAM SA
Human Error
• Three types of human error:
– Error of omission
• Not performing an act or behavior — just didn't do it
– Error of commission
• Performing a different act or behavior
– Extraneous error
• Performing an additional action


TEAM SA
Human Error
• Levels of consequences of human error
– Little or no effect
– Physical damage to equipment
– Personal injury
– Catastrophic event


TEAM SA
Dirty Dozen
• Lack of Communication
– A lack of clear direct statements and good, active listening skills.
• Complacency
– Self-satisfaction accompanied by a loss of awareness of the dangers.
• Lack of Knowledge
– Lack of experience or training in the task at hand.
• Distraction
– Draw one's attention away, mental emotional confusion or disturbance.
(Dupont)

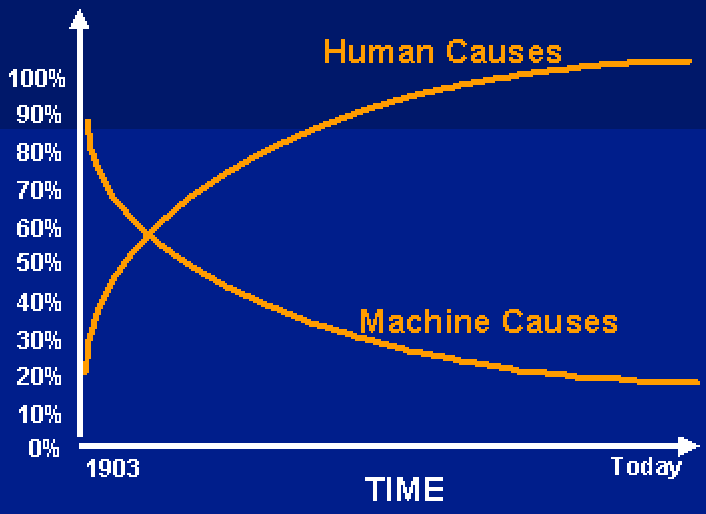

TEAM SA
Dirty Dozen
• Lack of Teamwork
– Lack of working together to achieve a common goal
• Fatigue
– Weariness from labor or exertion, nervous exhaustion, temporary loss of power to respond
• Lack of Resources
– Failure to use or acquire the appropriate tools, equipment, information and procedures for the task at hand
• Pressure
– Pushing for something in spite of opposing odds, creating a sense of urgency or haste
(Dupont)

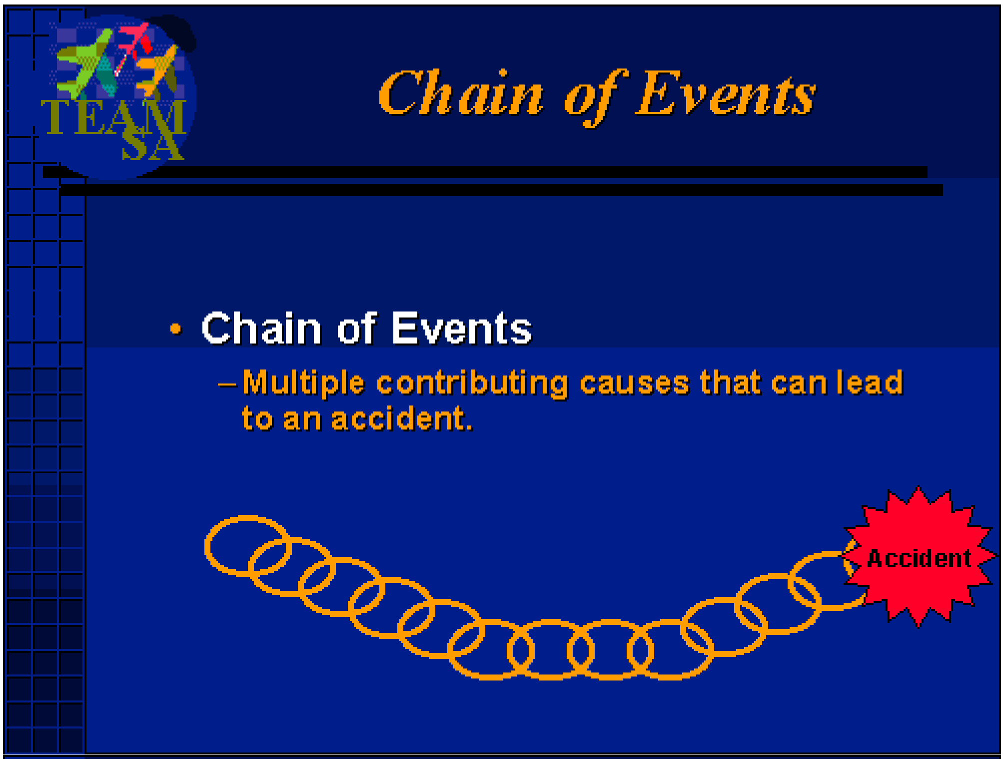

TEAM SA
Dirty Dozen
• Lack of Assertiveness
– A lack of positive communication of one's ideas, wants and needs.
• Stress
– Mental, emotional or physical tension, strain, or distress.
• Lack of Awareness
– Failure to be alert or vigilant in observing.
• Norms
– The commonly accepted practice of working routine jobs without the manual.
(Dupont)

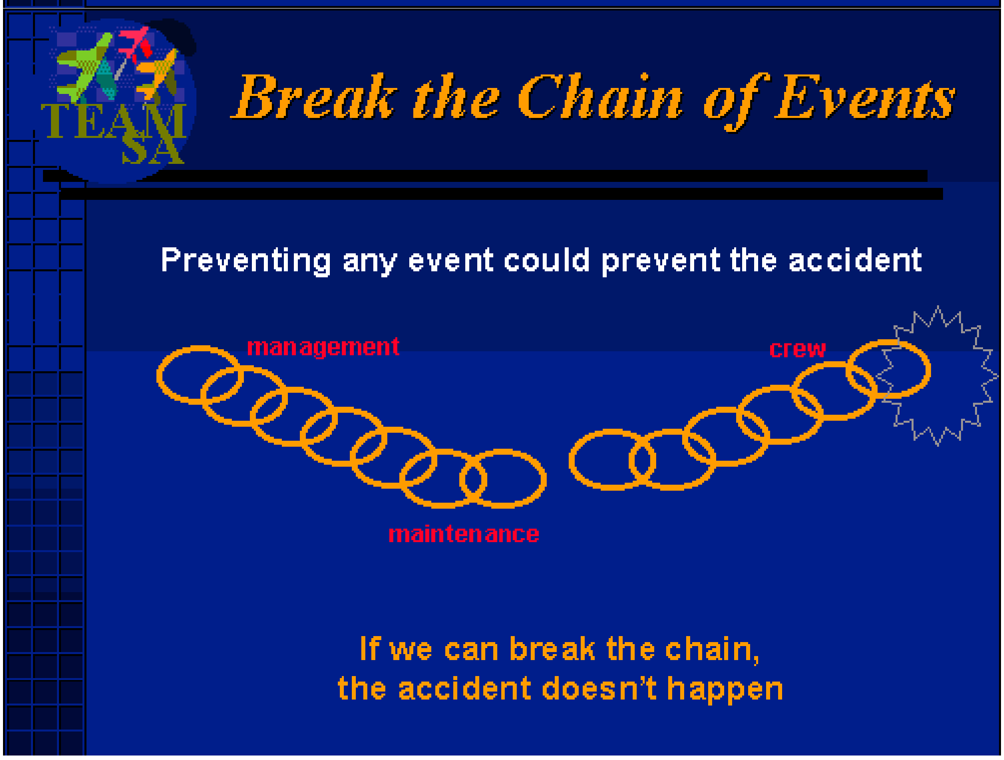
Accident

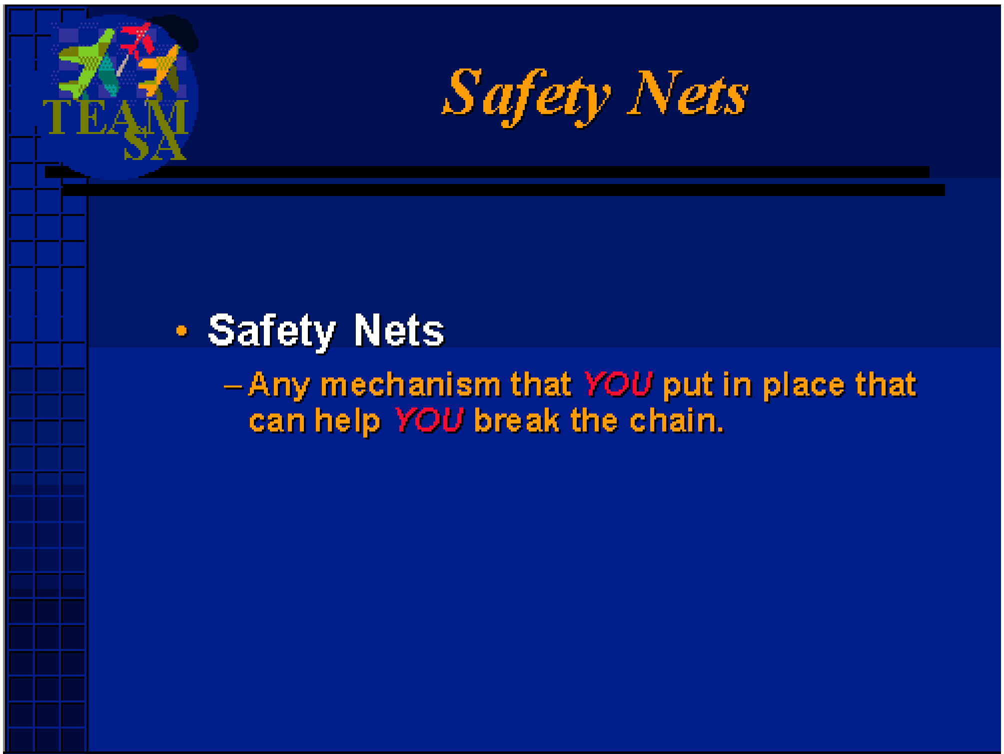
- An accident is caused by a variety of contributing factors that interfere with your good judgment
- This permits a series of events to develop, eventually resulting in damage to people or property.

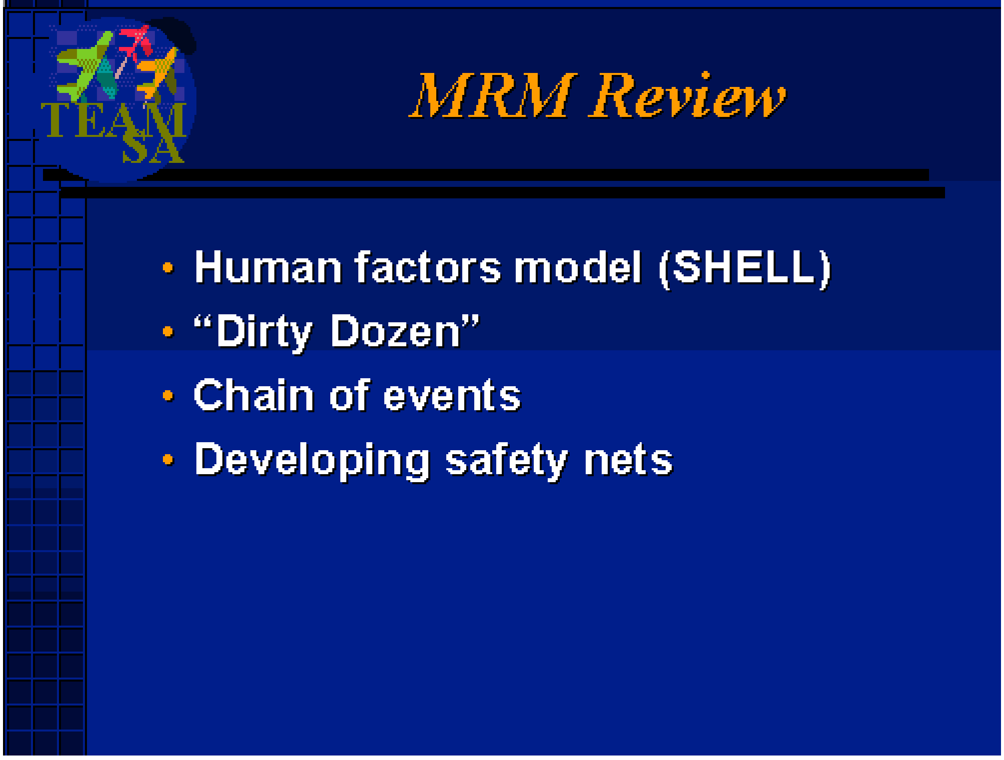
Aviation Accidents



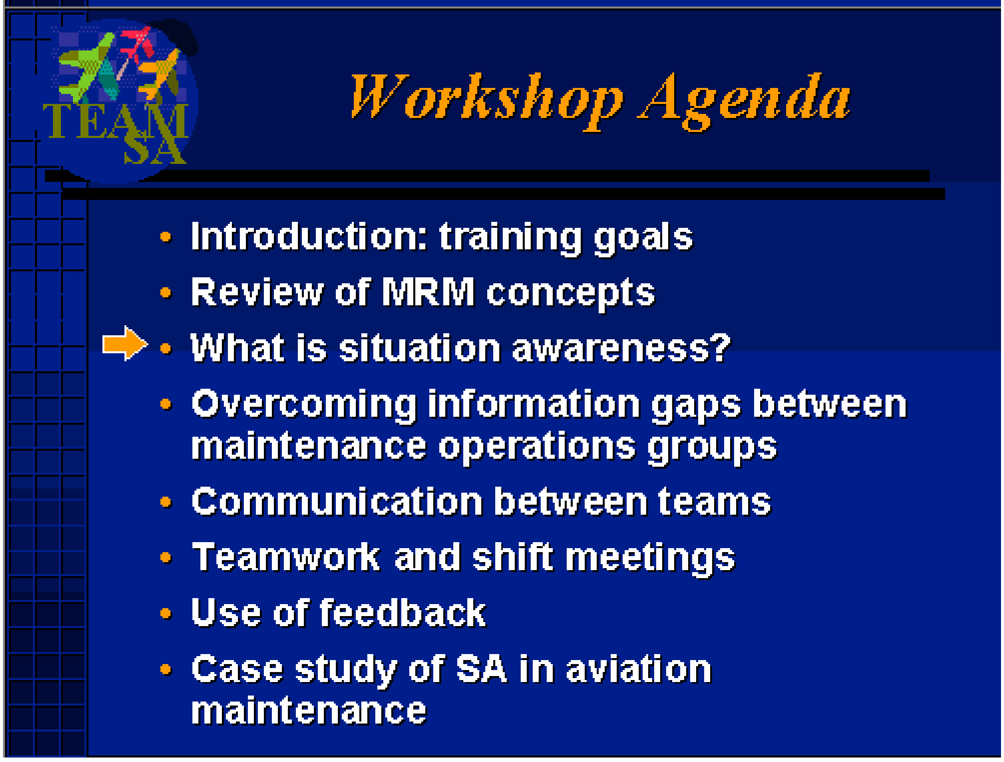

TEAM SA
Chain of Events
• Chain of Events
– Multiple contributing causes that can lead to an accident.
Accident


TEAM SA
Break the Chain of Events
Preventing any event could prevent the accident
management
crew
maintenance
If we can break the chain,
the accident doesn't happen


TEAM SA
Safety Nets
• Safety Nets
– Any mechanism that YOU put in place that can help YOU break the chain.


TEAM SA
MRM Review
• Human factors model (SHELL)
• "Dirty Dozen"
• Chain of events
• Developing safety nets


TEAM SA
MRM Exercise
• Maintenance Video
• Group Exercise:
– Identify Human Factors elements (SHELL)
– Recognize "Dirty Dozen"
– Identify Chain of events
– Develop Safety nets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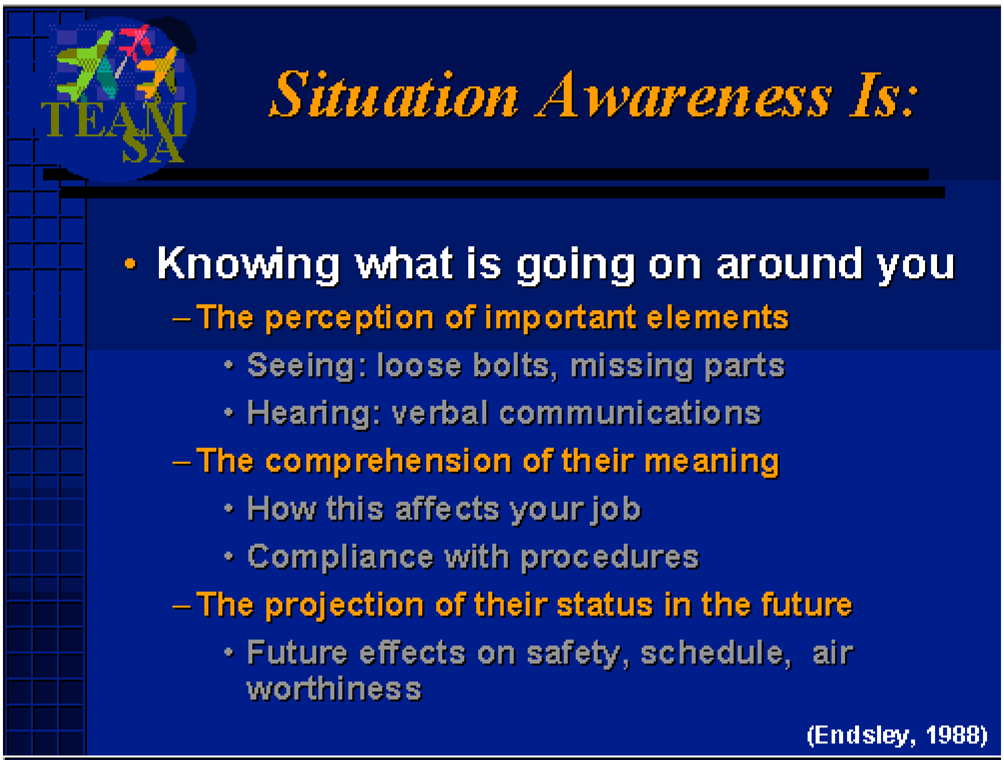
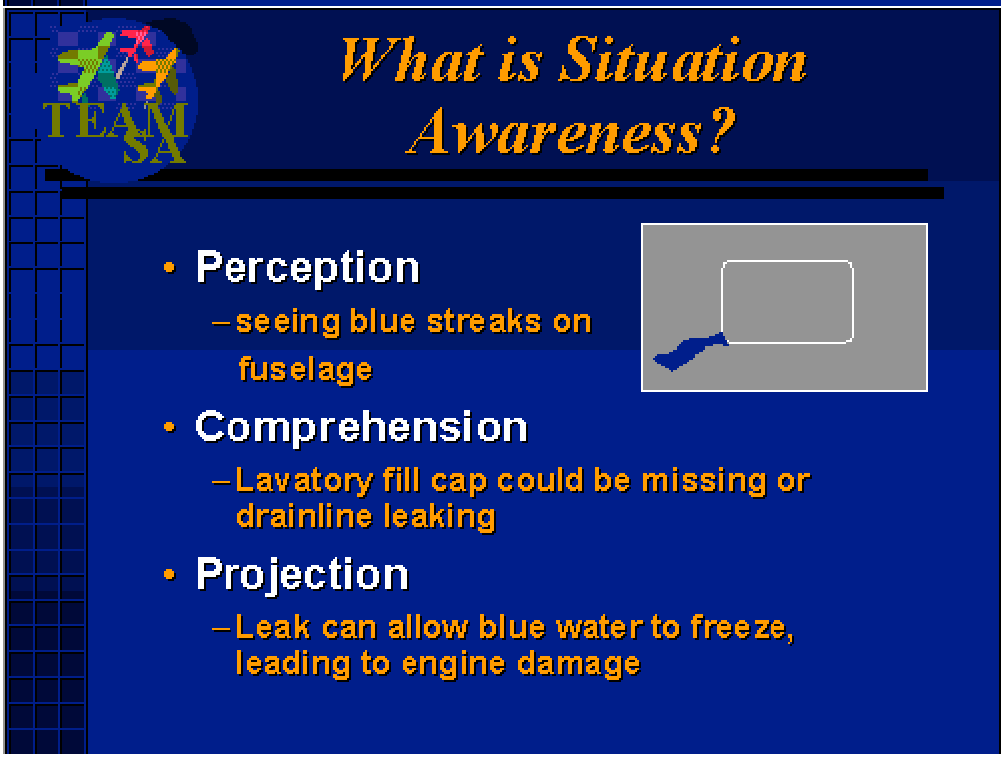
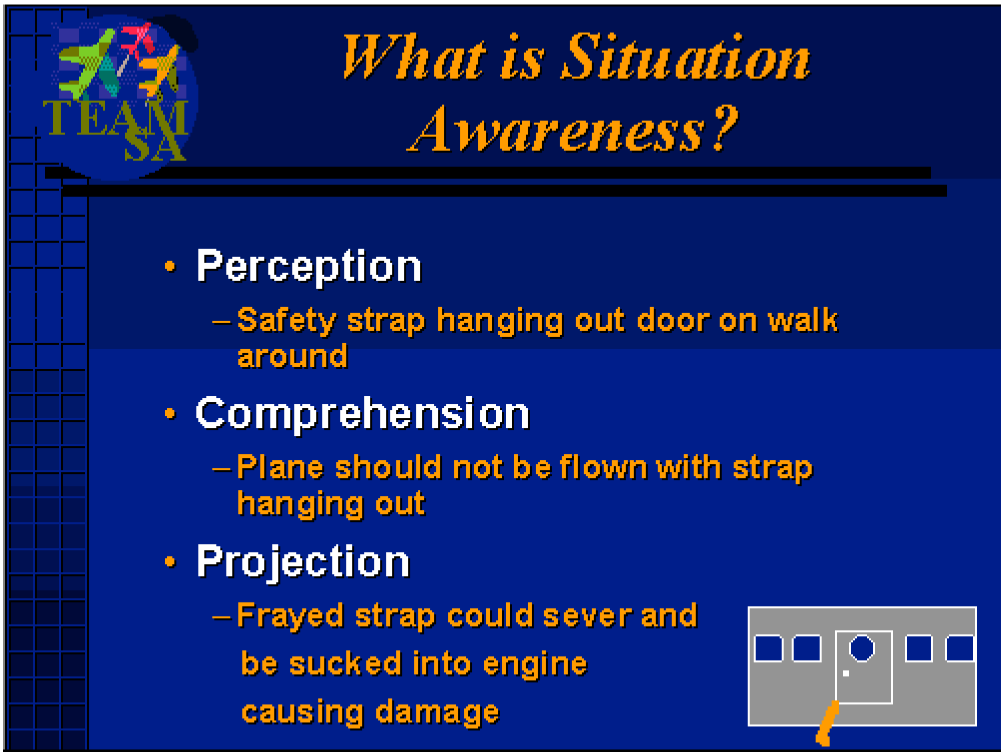
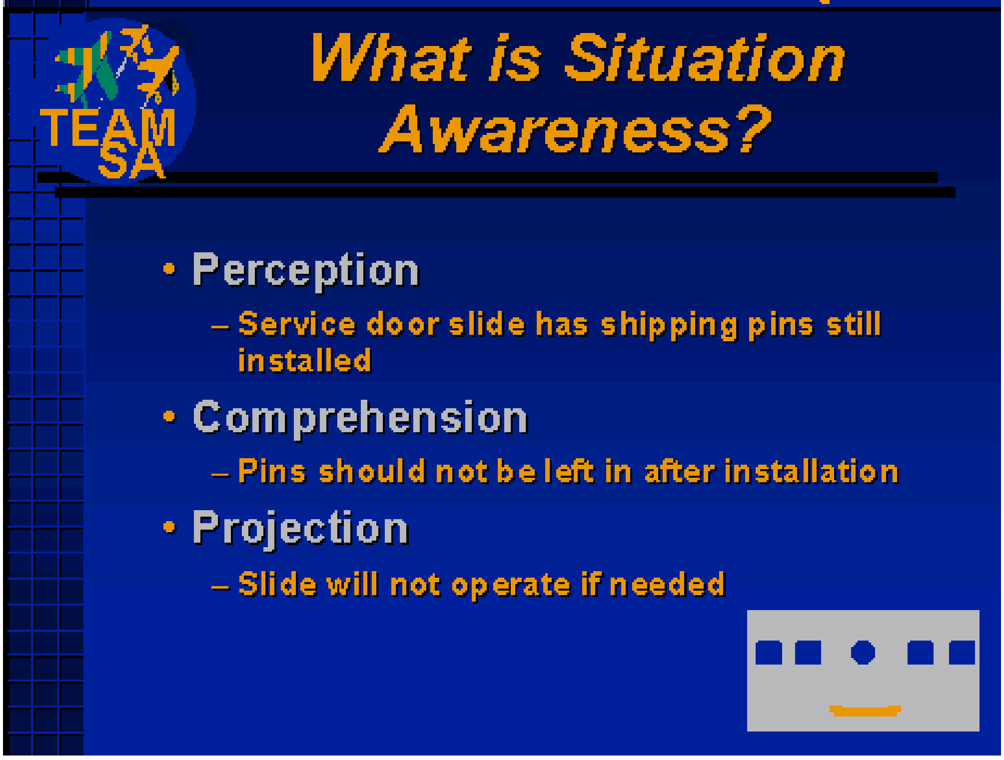
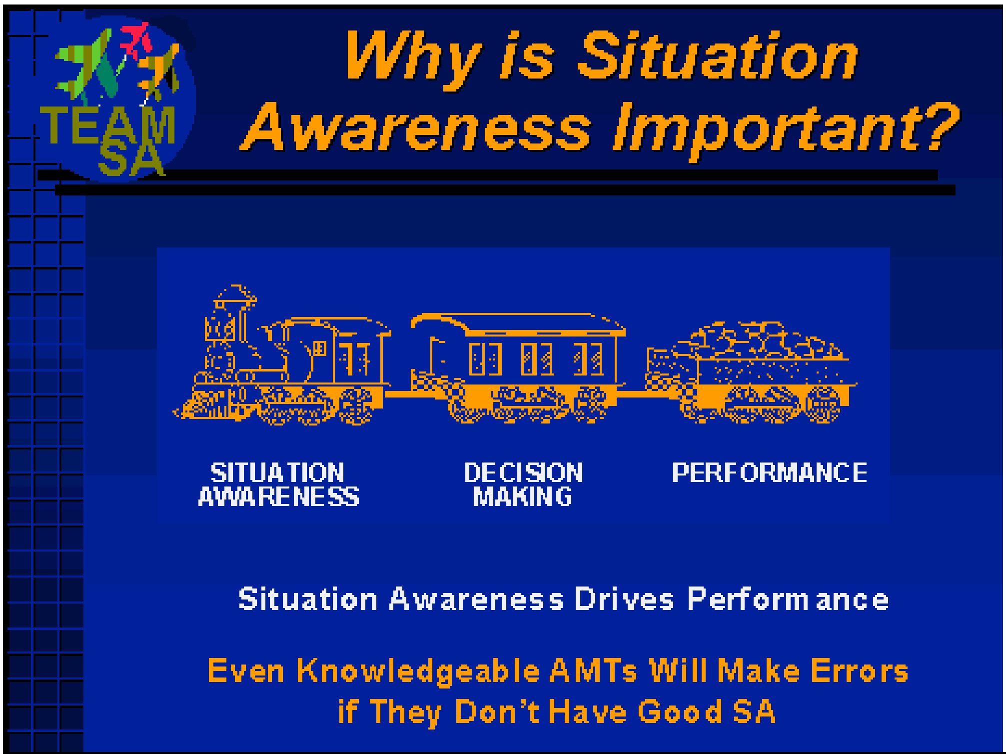
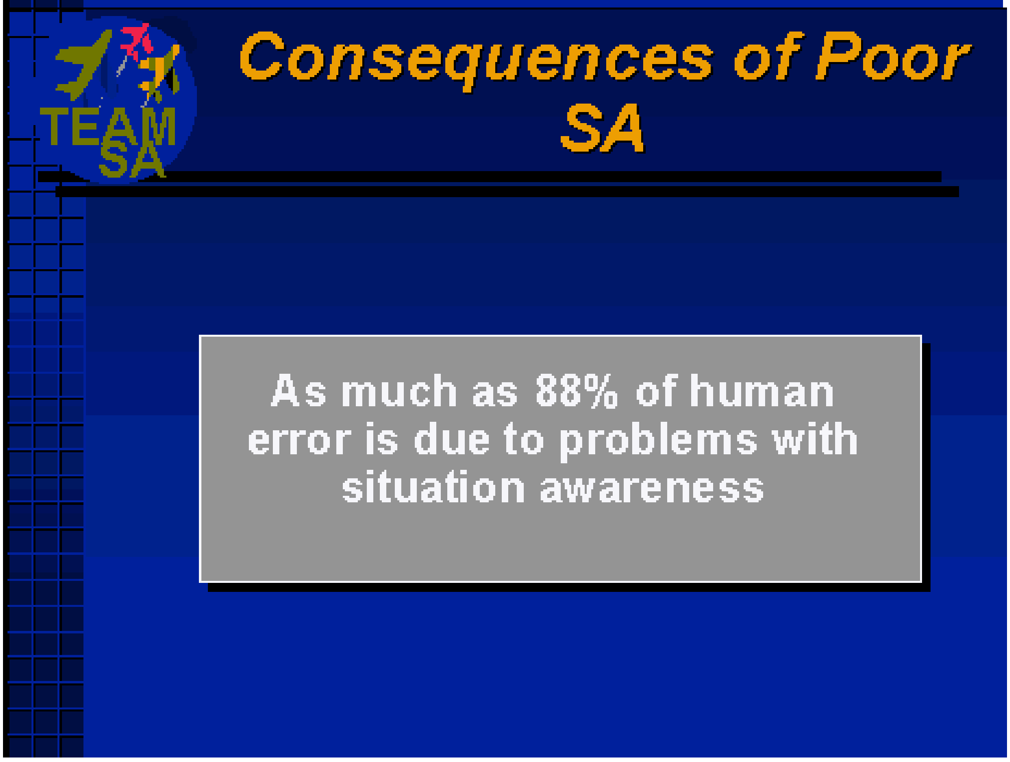

TEAM SA
Situation Awareness Is:
• Knowing what is going on around you
– The perception of important elements
• Seeing: loose bolts, missing parts
• Hearing: verbal communications
– The comprehension of their meaning
• How this affects your job
• Compliance with procedures
– The projection of their status in the future
• Future effects on safety, schedule, air worthiness
(Endsley, 1988)

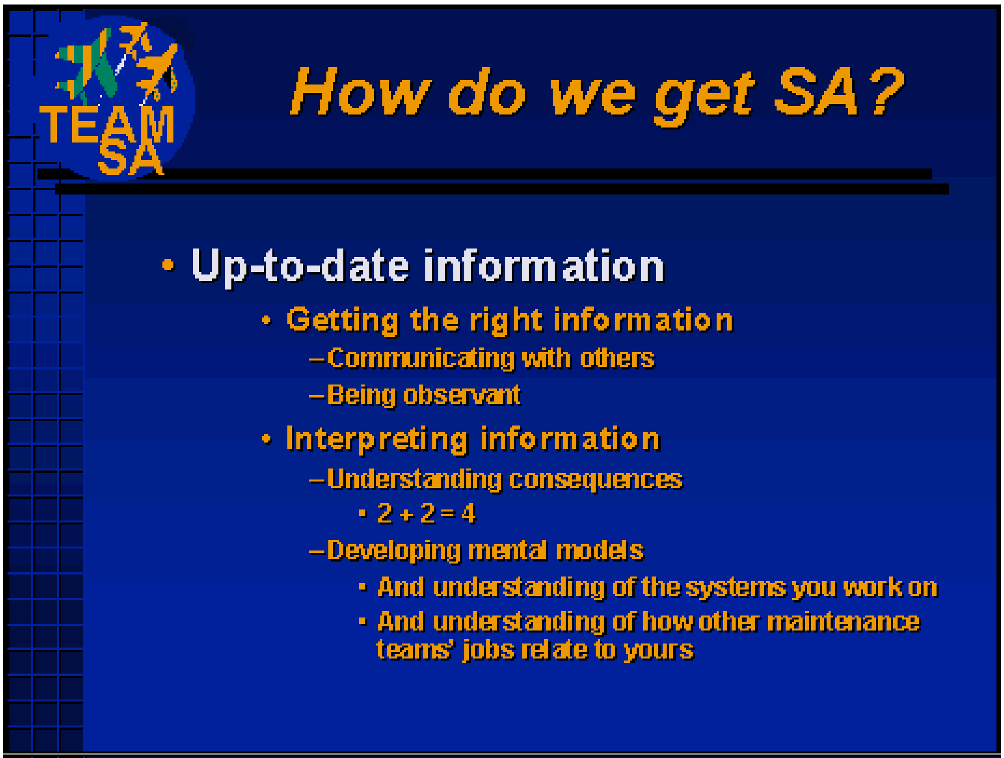

TEAM SA
What is Situation Awareness?
• Perception
– seeing blue streaks on fuselage
• Comprehension
– Lavatory fill cap could be missing or drainline leaking
• Projection
– Leak can allow blue water to freeze, leading to engine damage

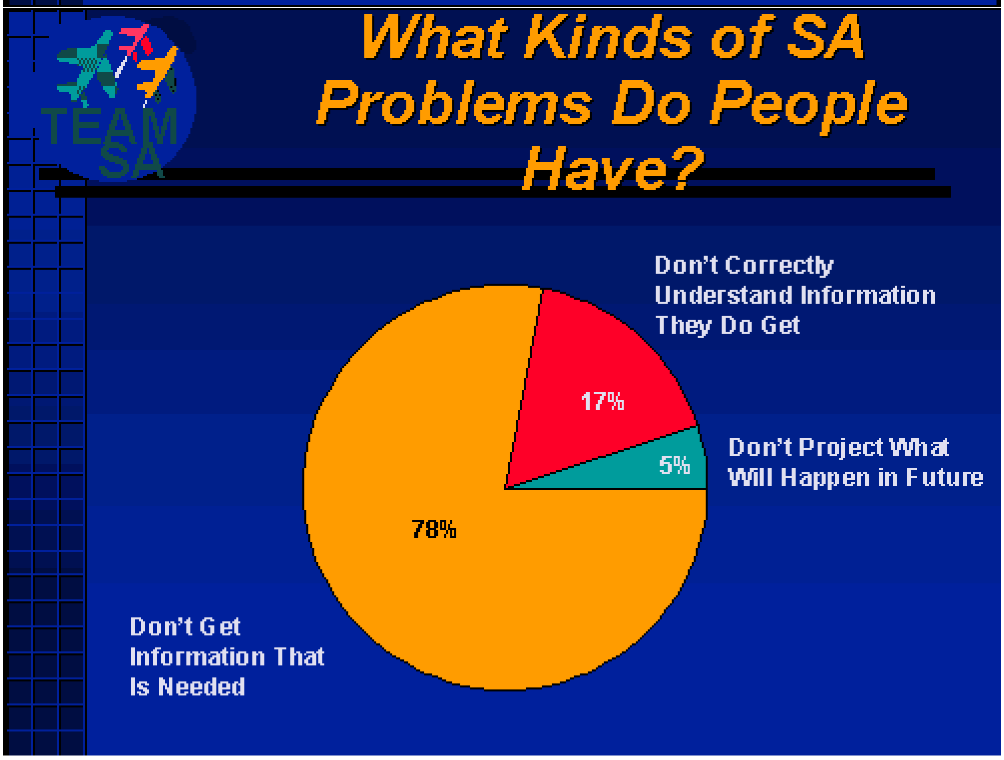

TEAM SA
What is Situation Awareness?
• Perception
– Safety strap hanging out door on walk around
• Comprehension
– Plane should not be flown with strap hanging out
• Projection
– Frayed strap could sever and be sucked into engine causing damage

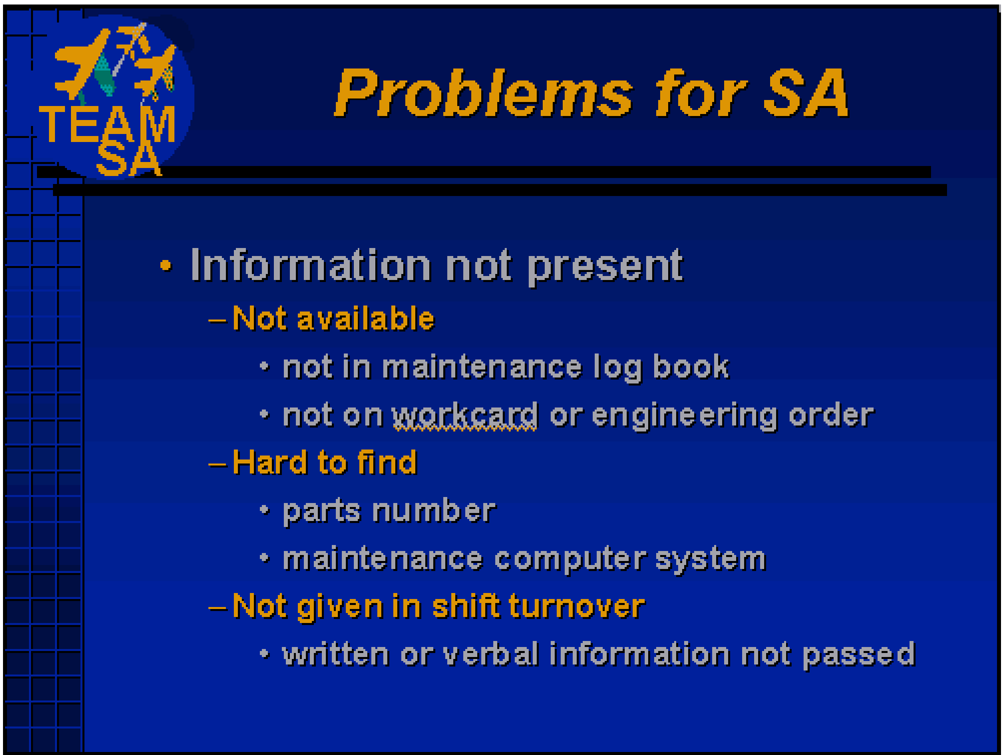

TEAM SA
What is Situation Awareness?
• Perception
– Service door slide has shipping pins still installed
• Comprehension
– Pins should not be left in after installation
• Projection
– Slide will not operate if needed

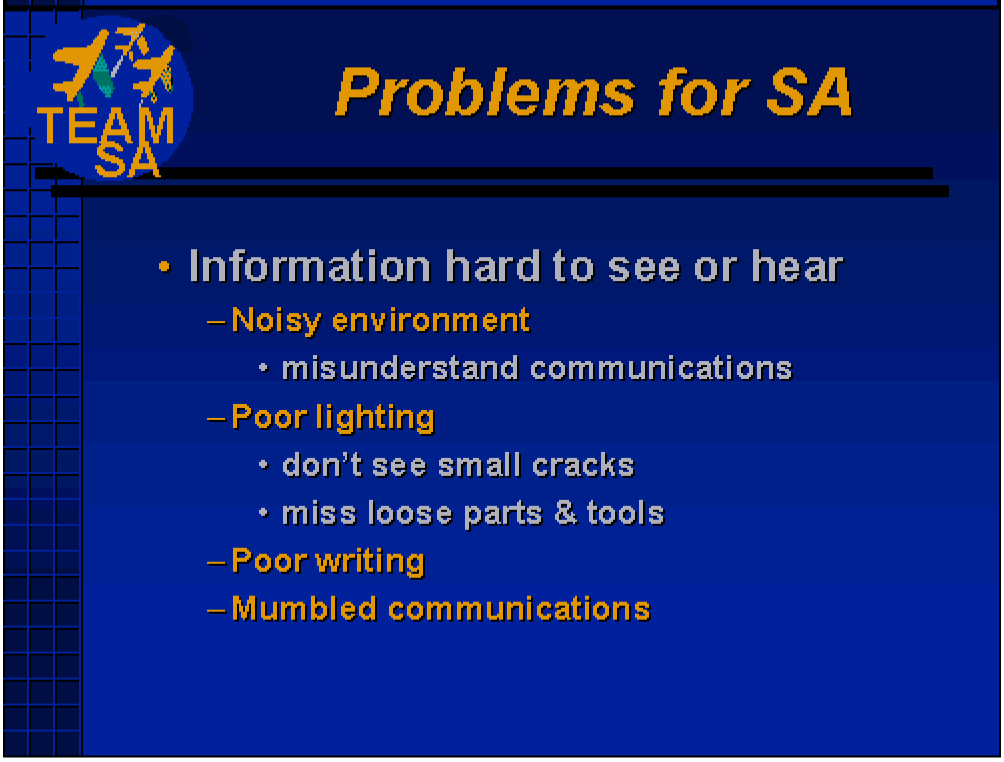

TEAM SA
Why is Situation Awareness Important?
SITUATION AWARENESS
DECISION MAKING
PERFORMANCE
Situation Awareness Drives Performance
Even Knowledgeable AMTs Will Make Errors if They Don't Have Good SA

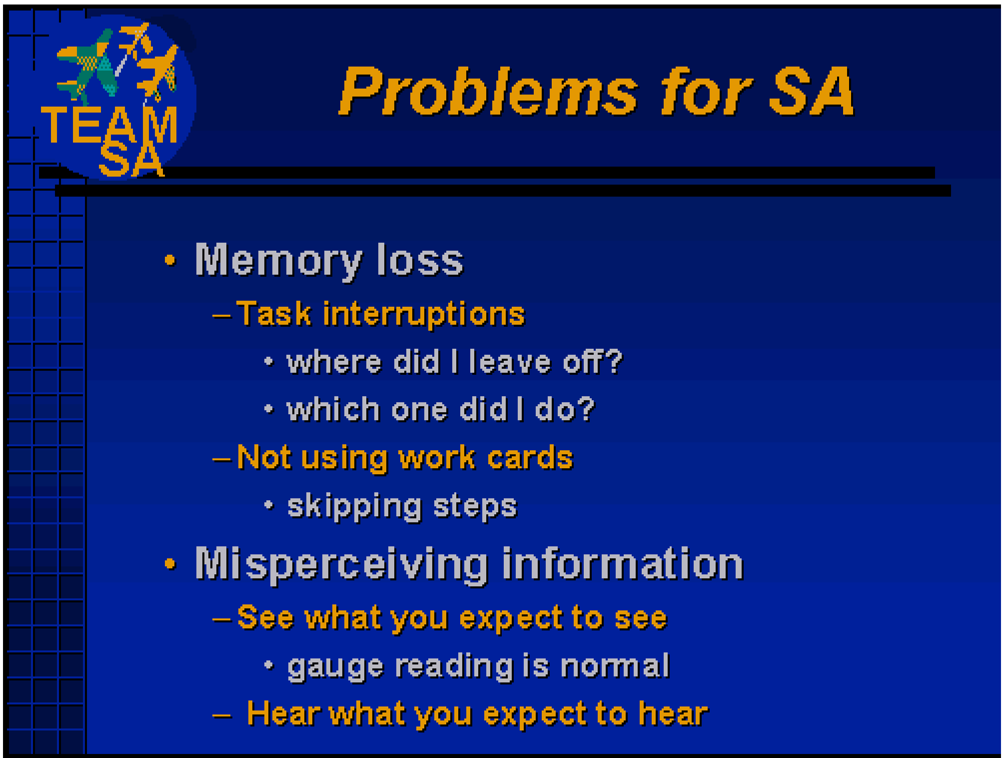

TEAM SA
Consequences of Poor SA
As much as 88% of human error is due to problems with situation awareness

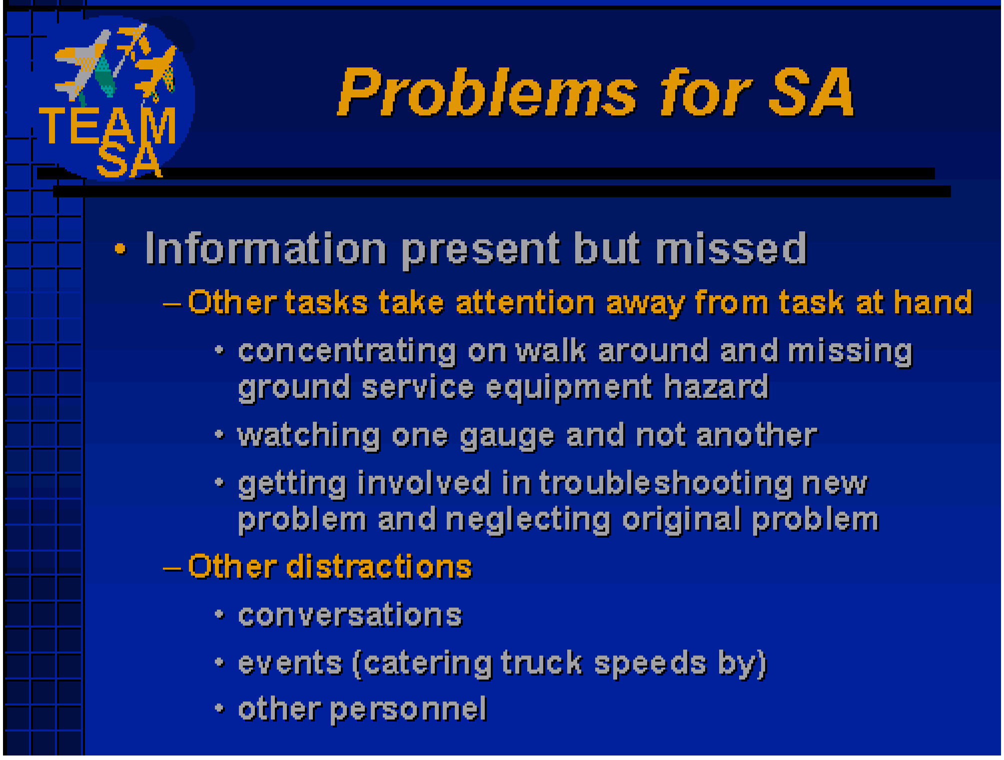

TEAM SA
How do we get SA?
• Up-to-date information
• Getting the right information
–Communicating with others
–Being observant
• Interpreting information
–Understanding consequences
▪ 2 + 2 = 4
–Developing mental models
▪ And understanding of the systems you work on
▪ And understanding of how other maintenance teams' jobs relate to yours

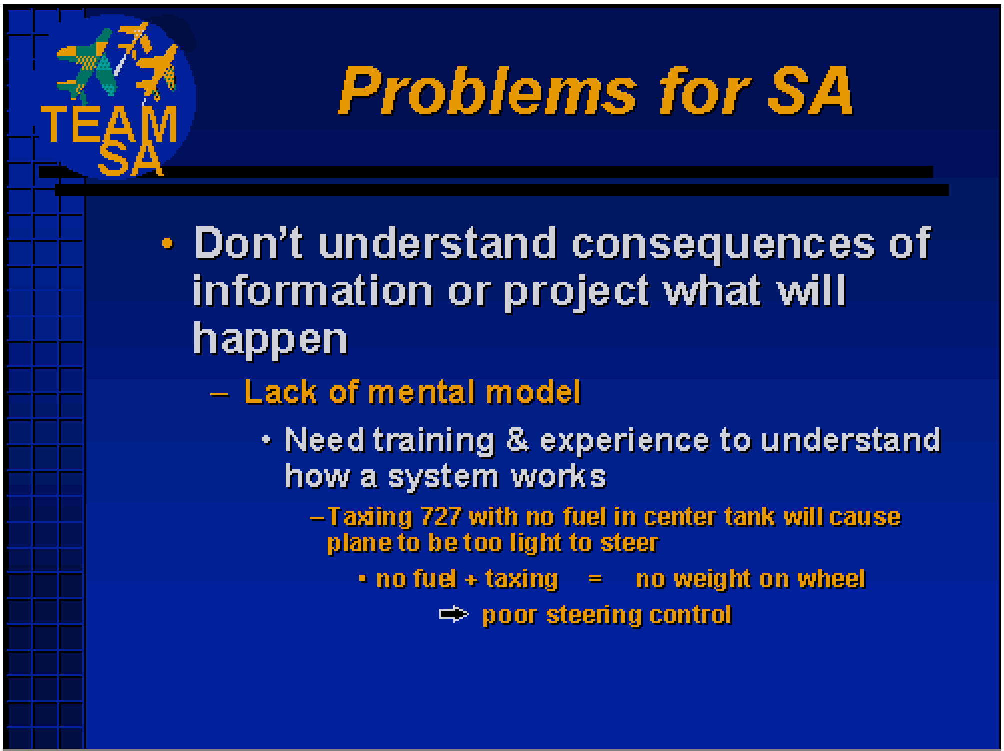

TEAM SA
What Kinds of SA Problems Do People Have?
Don't Correctly Understand Information They Do Get
17%
5%
Don't Project What Will Happen in Future
78%
Don't Get Information That Is Needed

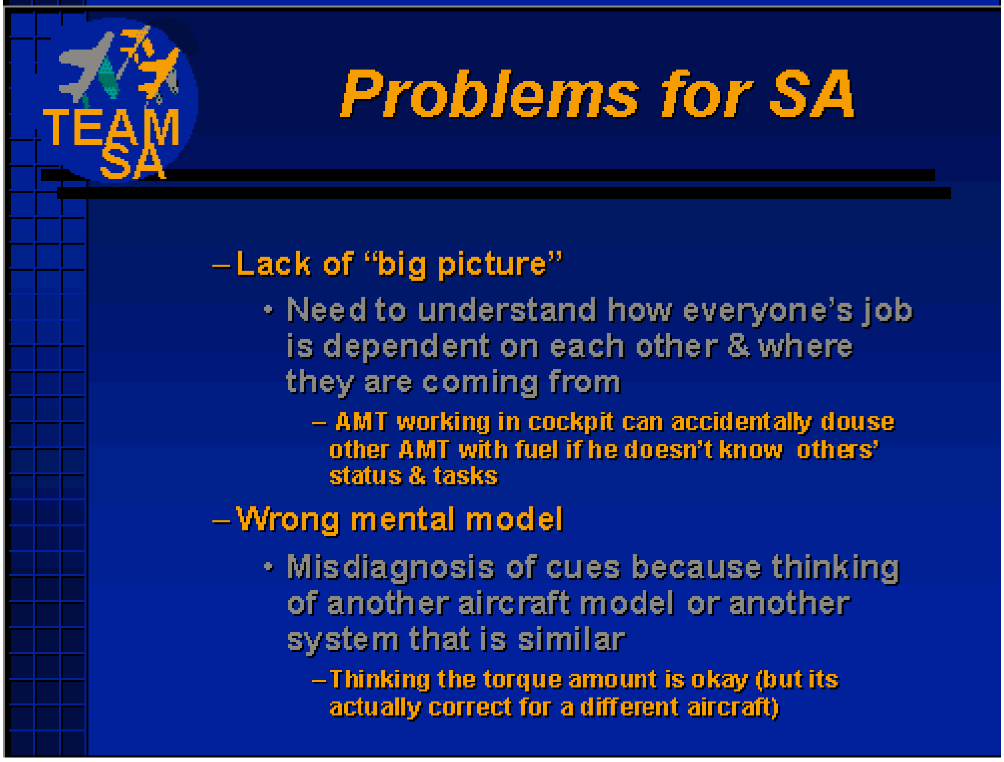

TEAM SA
Problems for SA
• Information not present
– Not available
• not in maintenance log book
• not on workcard or engineering order
– Hard to find
• parts number
• maintenance computer system
– Not given in shift turnover
• written or verbal information not passed

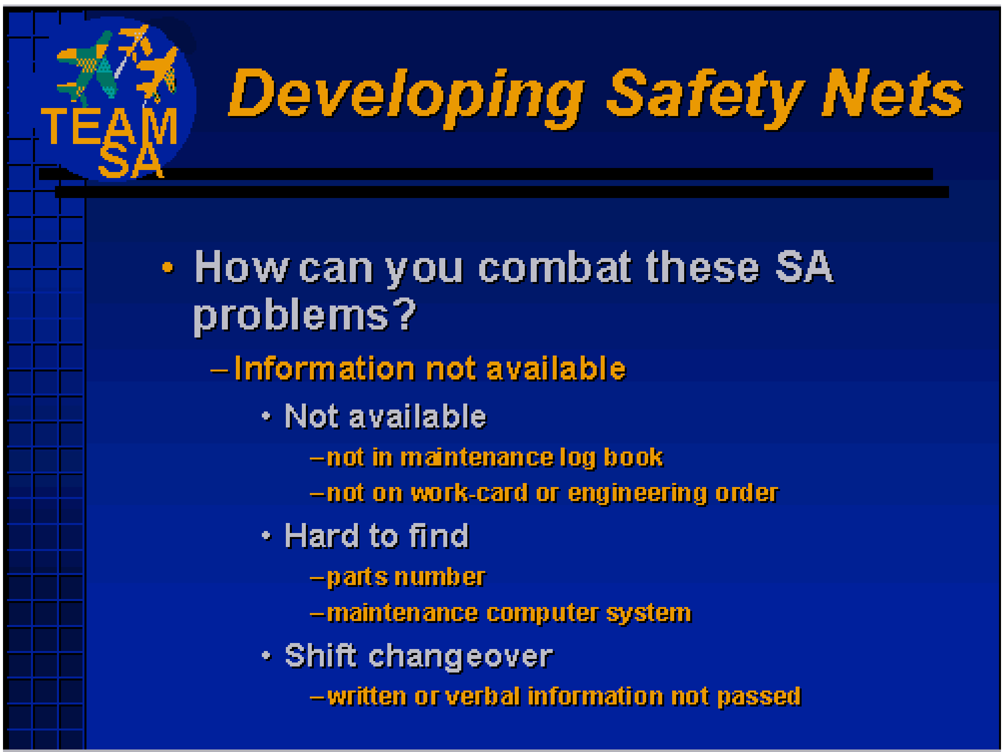

TEAM SA
Problems for SA
• Information hard to see or hear
– Noisy environment
• misunderstand communications
– Poor lighting
• don't see small cracks
• miss loose parts & tools
– Poor writing
– Mumbled communications

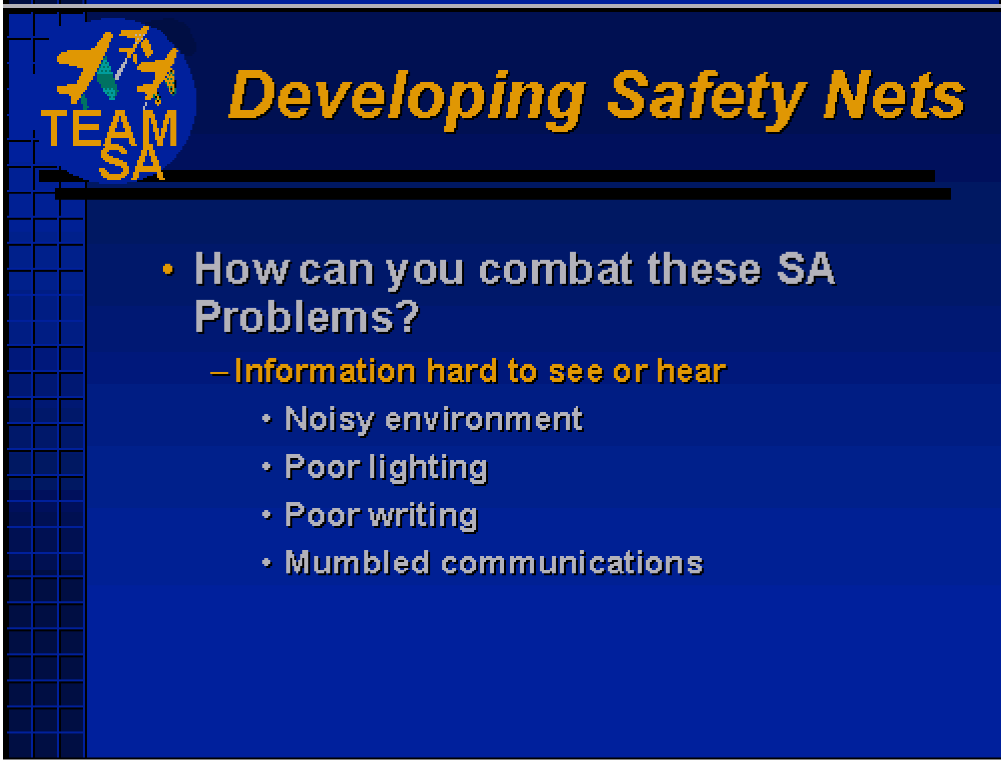

TEAM SA
Problems for SA
• Memory loss
– Task interruptions
• where did I leave off?
• which one did I do?
– Not using work cards
• skipping steps
• Misperceiving information
– See what you expect to see
• gauge reading is normal
– Hear what you expect to hear


TEAM SA
Problems for SA
• Information present but missed
– Other tasks take attention away from task at hand
• concentrating on walk around and missing ground service equipment hazard
• watching one gauge and not another
• getting involved in troubleshooting new problem and neglecting original problem
– Other distractions
• conversations
• events (catering truck speeds by)
• other personnel


TEAM SA
Problems for SA
• Don't understand consequences of information or project what will happen
– Lack of mental model
• Need training & experience to understand how a system works
– Taxiing 727 with no fuel in center tank will cause plane to be too light to steer
• no fuel + taxiing = no weight on wheel
⇨ poor steering control


TEAM SA
Problems for SA
– Lack of "big picture"
• Need to understand how everyone's job is dependent on each other & where they are coming from
– AMT working in cockpit can accidentally douse other AMT with fuel if he doesn't know others' status & tasks
– Wrong mental model
• Misdiagnosis of cues because thinking of another aircraft model or another system that is similar
– Thinking the torque amount is okay (but its actually correct for a different aircraft)


TEAM SA
Developing Safety Nets
• How can you combat these SA problems?
– Information not available
• Not available
– not in maintenance log book
– not on work-card or engineering order
• Hard to find
– parts number
– maintenance computer system
• Shift changeover
– written or verbal information not passed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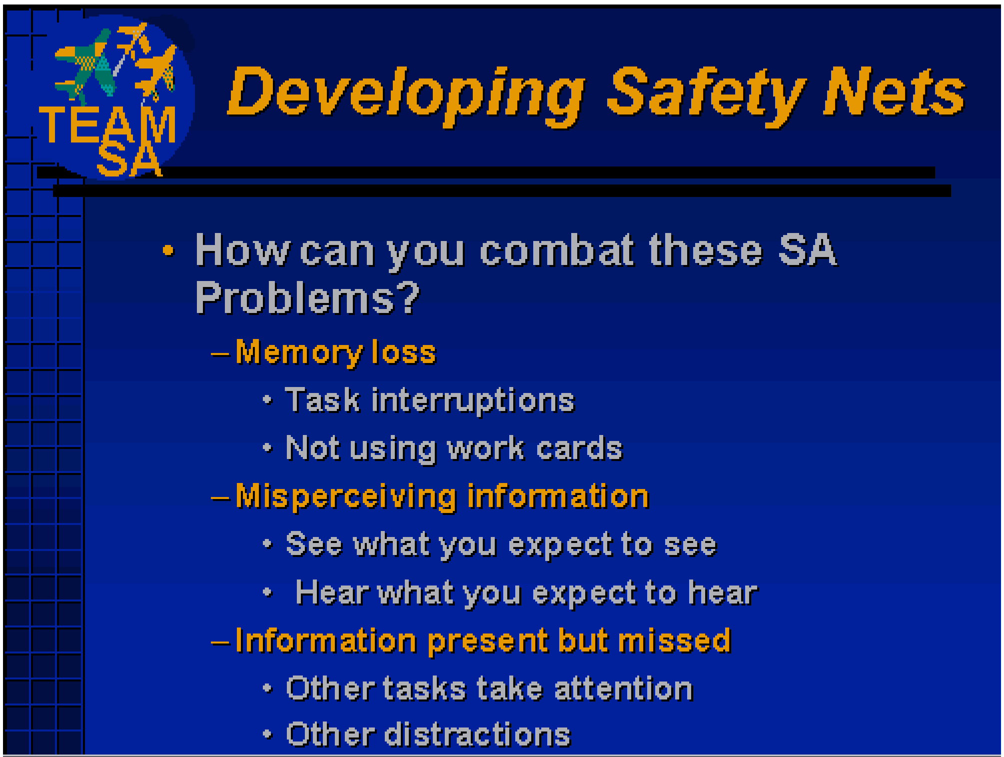
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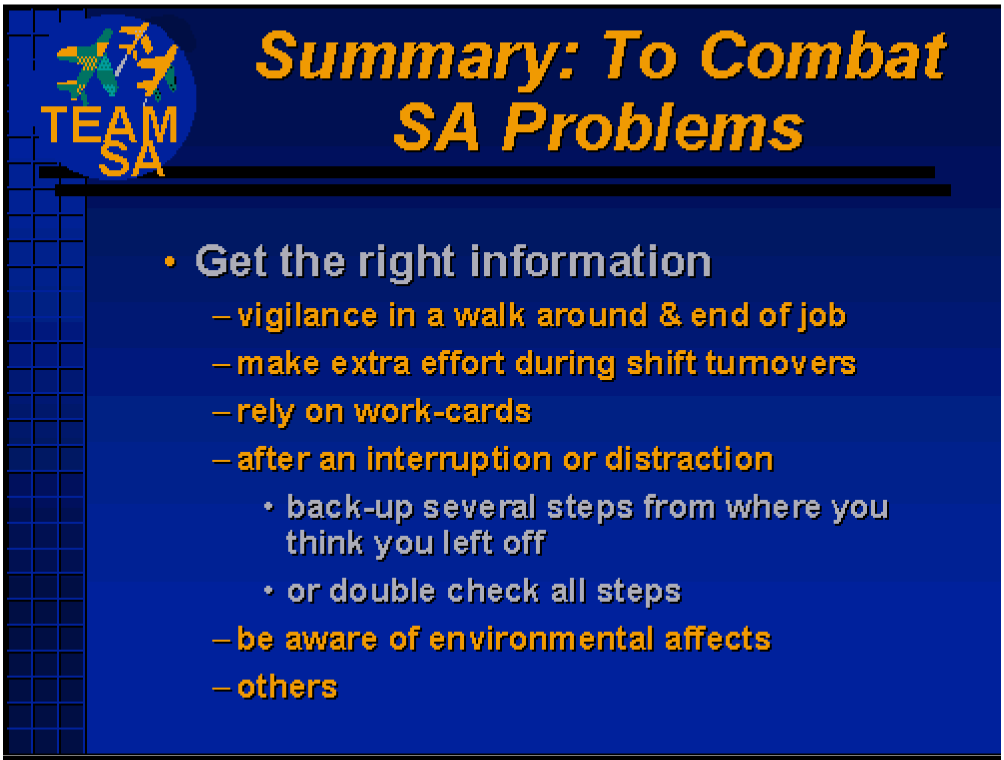
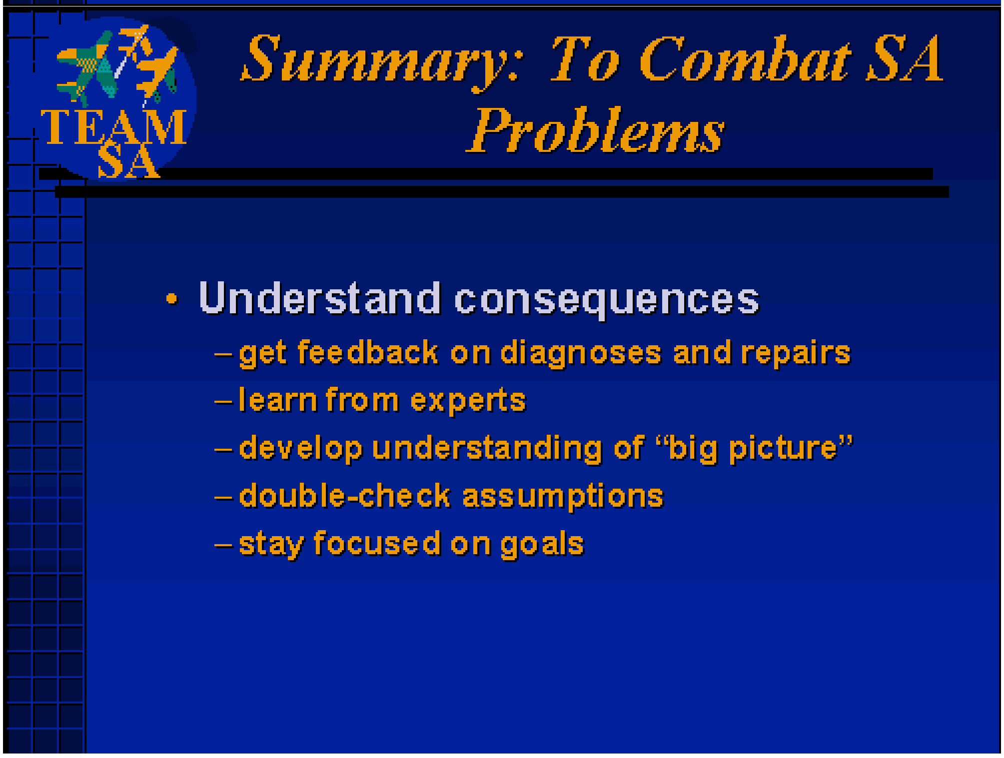
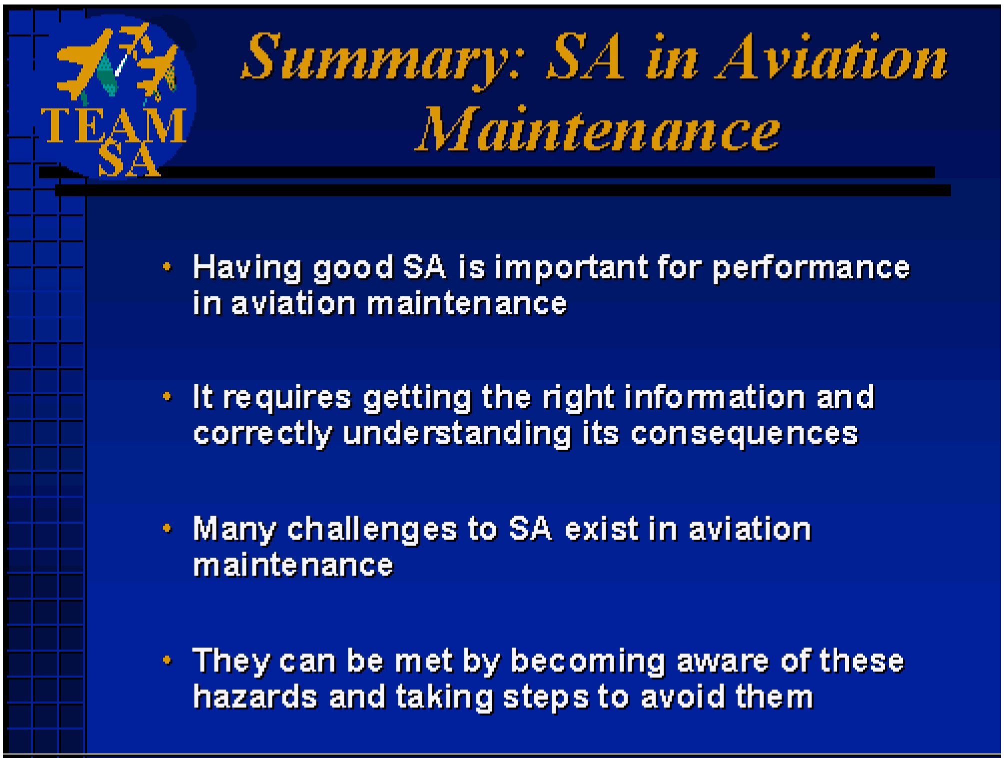
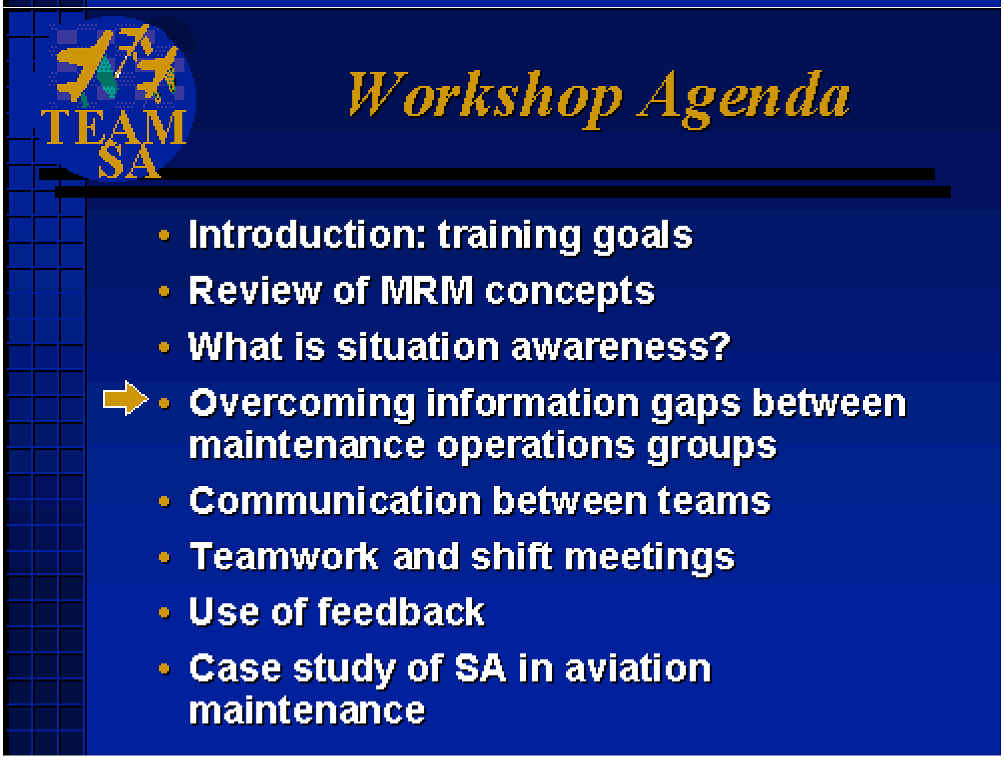
– Memory loss
• Task interruptions
• Not using work cards
– Misperceiving information
• See what you expect to see
• Hear what you expect to hear
– Information present but missed
• Other tasks take attention
• Other distractions


TEAM SA
Developing Safety Nets
• How can you combat these SA Problems?
– Don't understand consequences of information or project what will happen
• Lack of mental model
• Lack of "big picture"
• Wrong mental model


TEAM SA
Summary: To Combat SA Problems
• Get the right information
– vigilance in a walk around & end of job
– make extra effort during shift turnovers
– rely on work-cards
– after an interruption or distraction
• back-up several steps from where you think you left off
• or double check all steps
– be aware of environmental affects
– others


TEAM SA
Summary: To Combat SA Problems
• Understand consequences
– get feedback on diagnoses and repairs
– learn from experts
– develop understanding of “big picture”
– double-check assumptions
– stay focused on goals


TEAM SA
Summary: SA in Aviation Maintenance
Having good SA is important for performance in aviation maintenance
It requires getting the right information and correctly understanding its consequences
Many challenges to SA exist in aviation maintenance
They can be met by becoming aware of these hazards and taking steps to avoid them


TEAM SA
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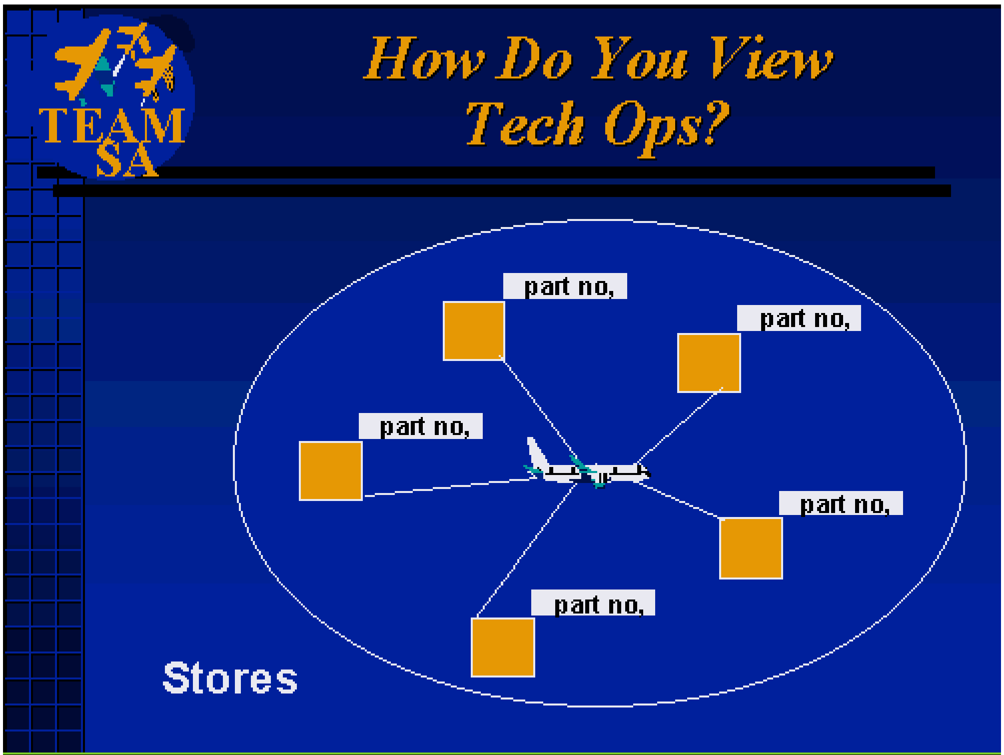
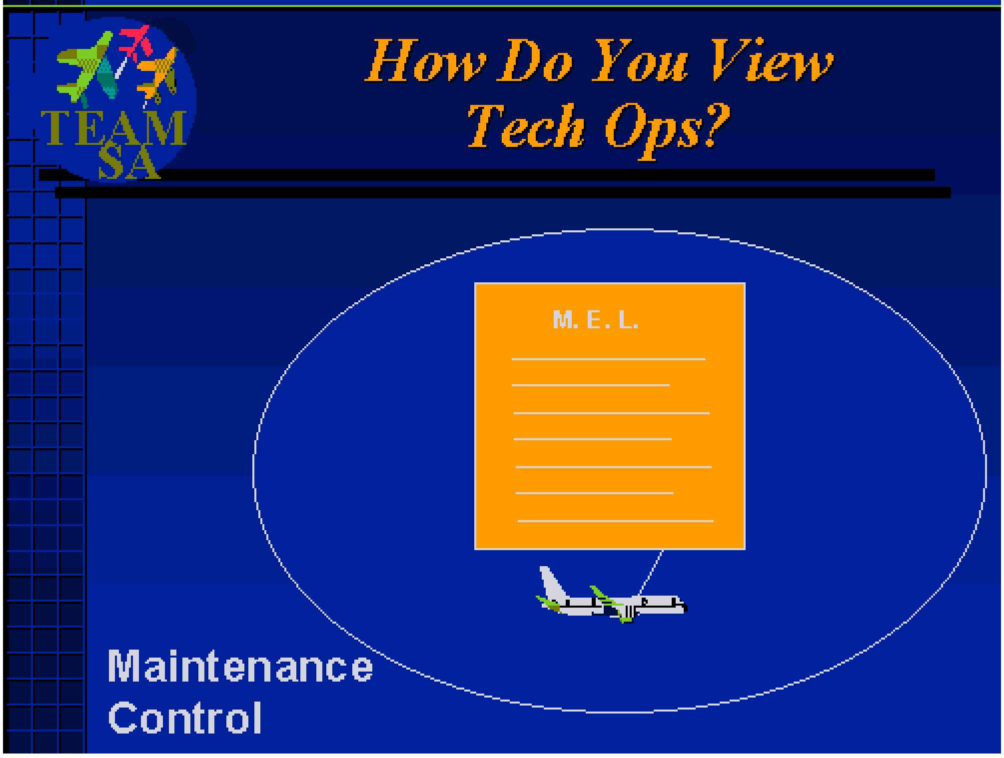
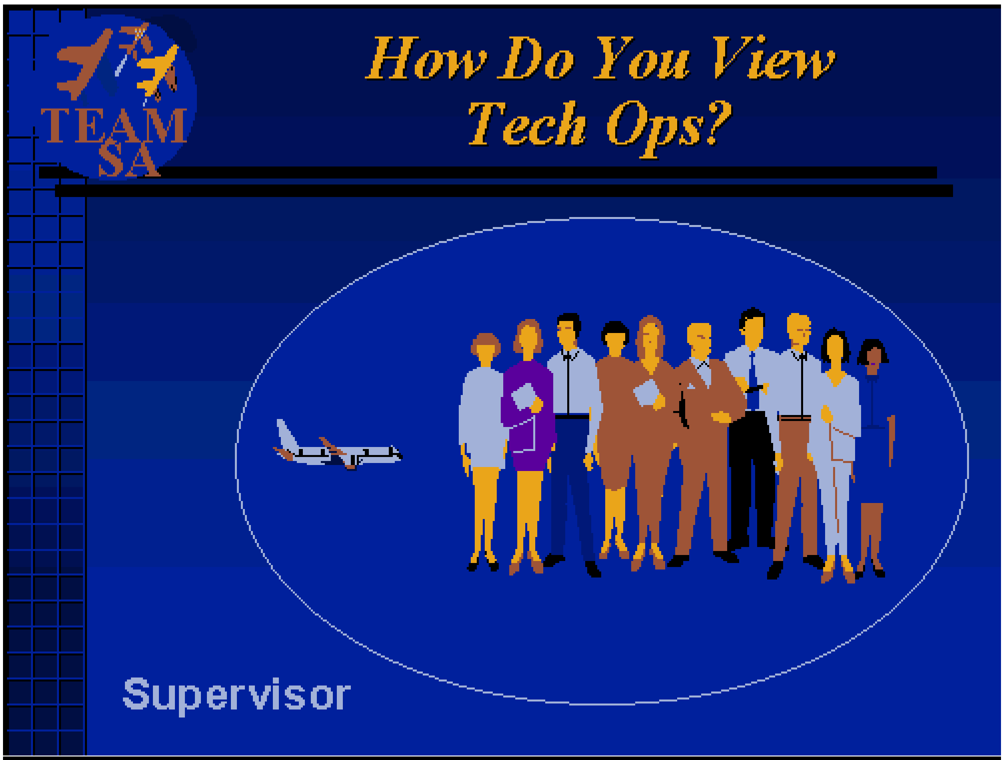
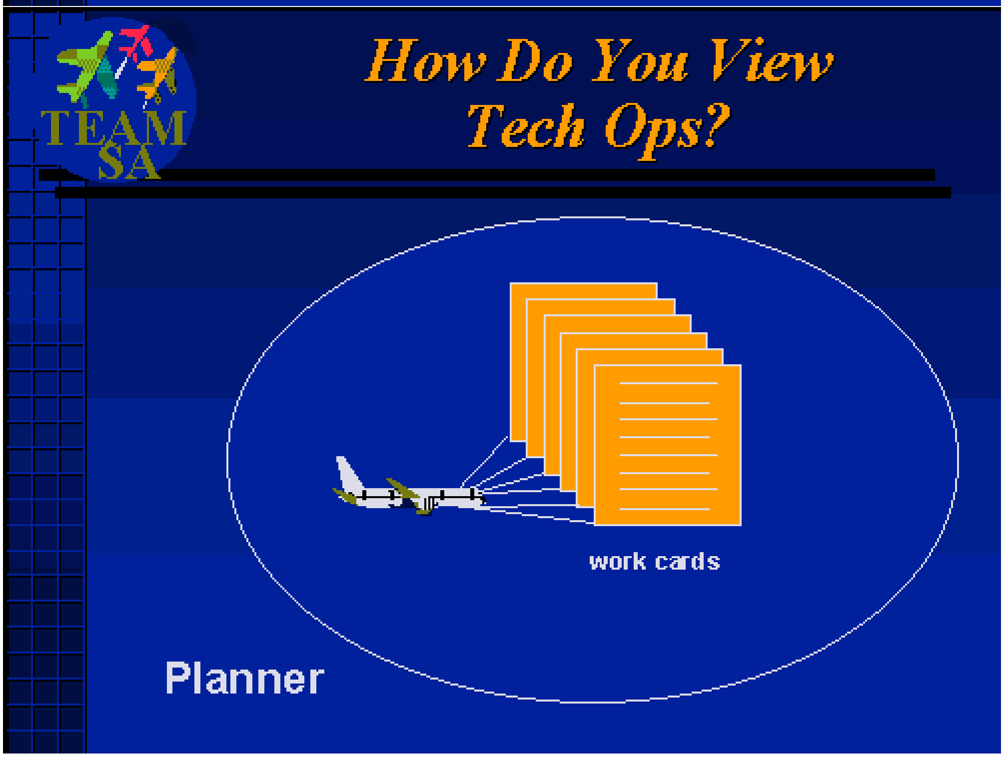
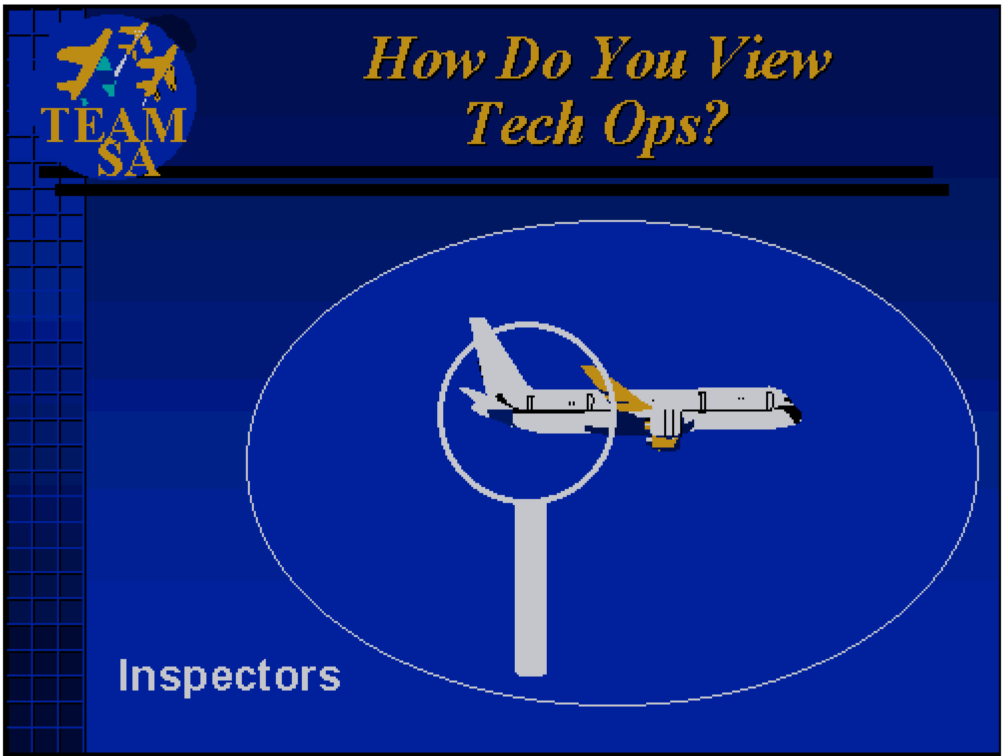
Case study of SA in aviation maintenance

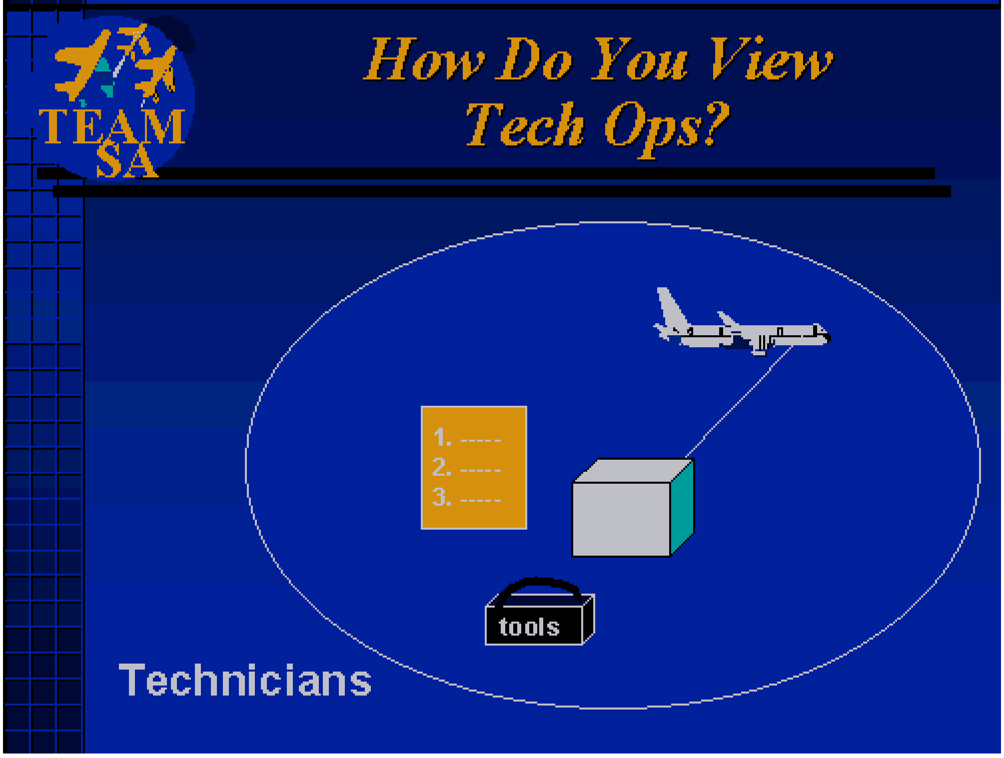

TEAM SA
How Do You View Tech Ops?
part no,
part no,
part no,
part no,
part no,
Stores


TEAM SA
How Do You View Tech Ops?
M. E. L.
Maintenance Control

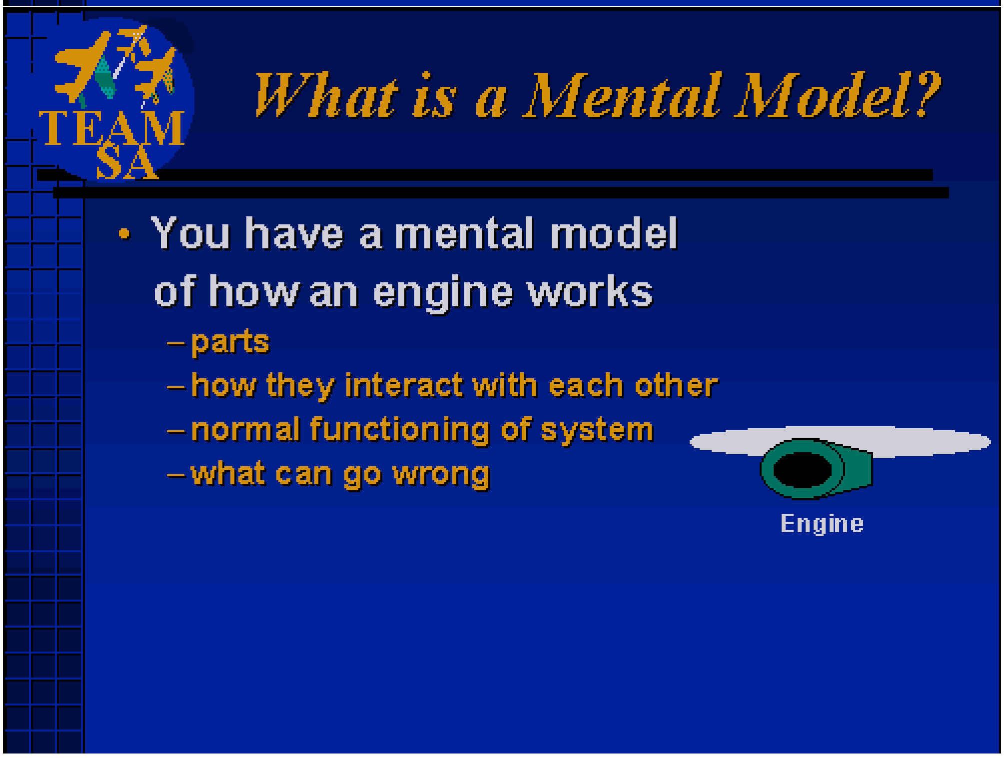

TEAM SA
How Do You View Tech Ops?
Supervisor

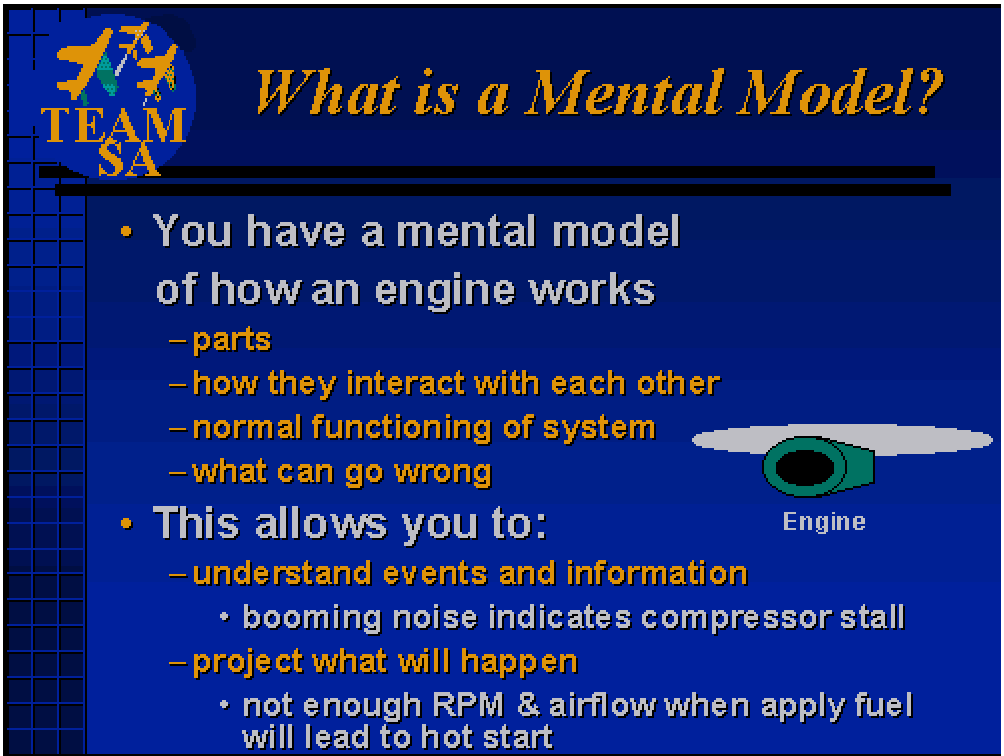

TEAM SA
How Do You View Tech Ops?
work cards
Planner

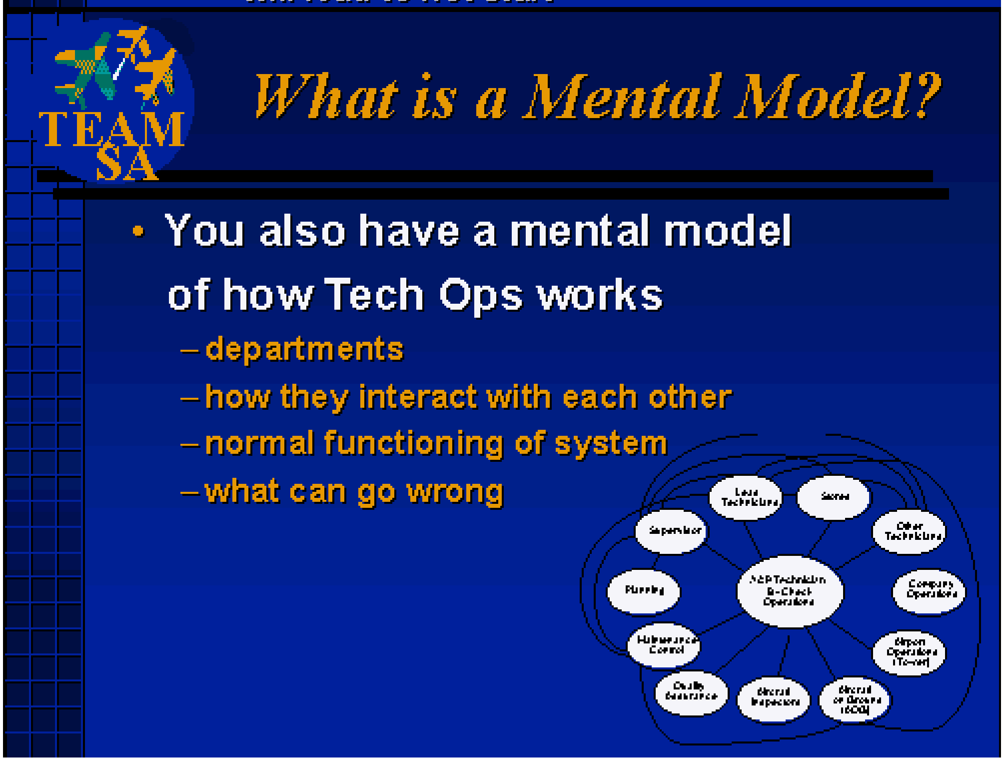

TEAM SA
How Do You View Tech Ops?
Inspectors

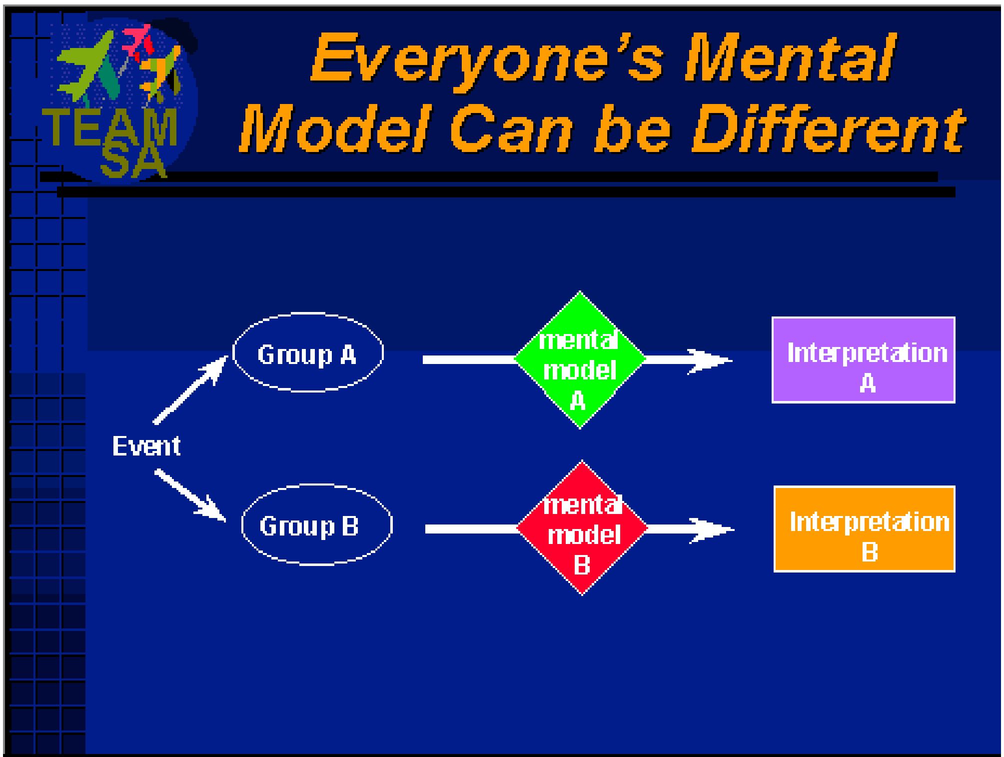

TEAM SA
How Do You View Tech Ops?
1. -----
2. -----
3. -----
tools
Technicians

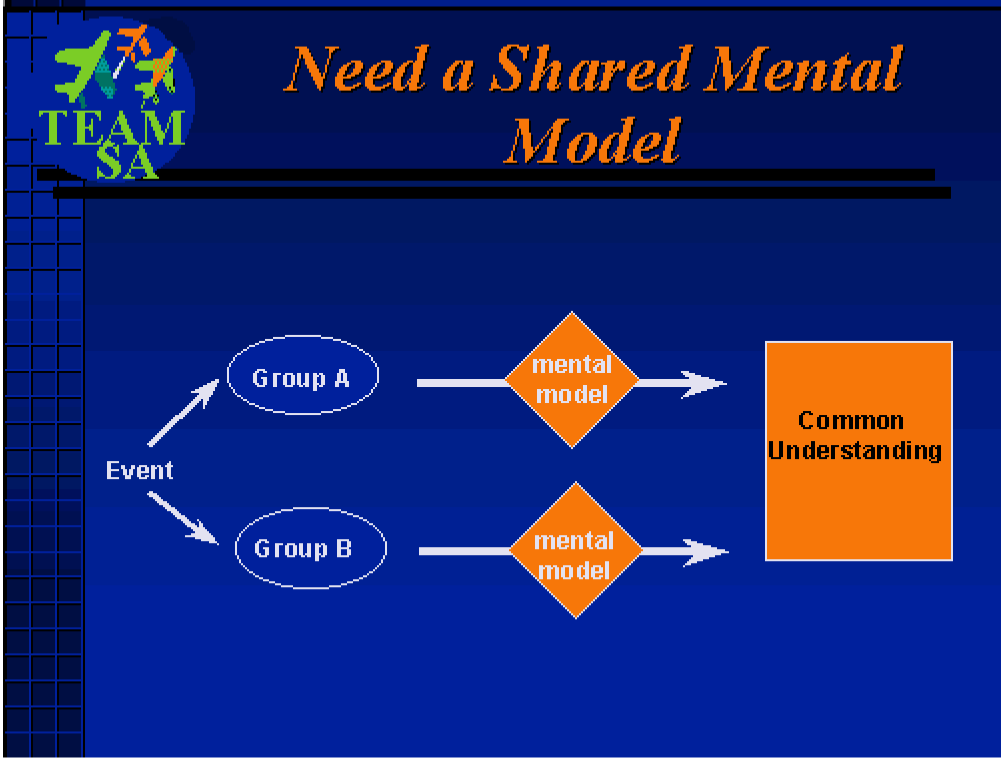

TEAM SA
We Each Have a Different Picture of Tech Ops
• Different groups have different goals and different roles
– The requirements are different
• We each see different sets of information

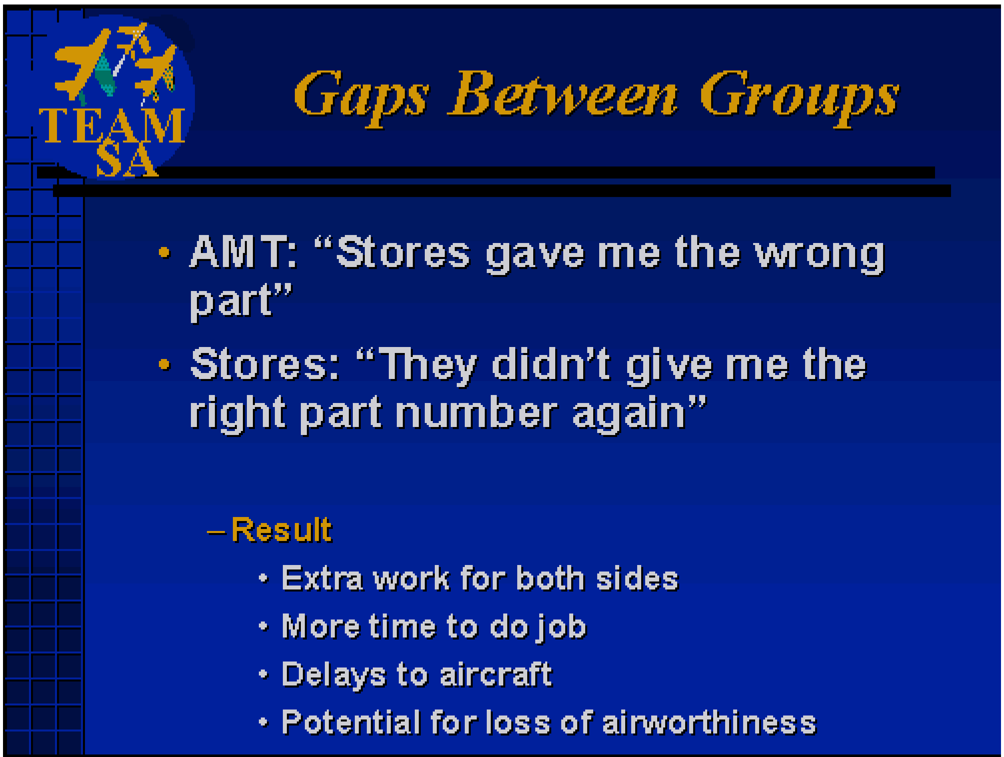

TEAM SA
What is a Mental Model?
• You have a mental model of how an engine works
– parts
– how they interact with each other
– normal functioning of system
– what can go wrong
Engine


TEAM SA
What is a Mental Model?
• You have a mental model of how an engine works
– parts
– how they interact with each other
– normal functioning of system
– what can go wrong
Engine
• This allows you to:
– understand events and information
• booming noise indicates compressor stall
– project what will happen
• not enough RPM & airflow when apply fuel will lead to hot start

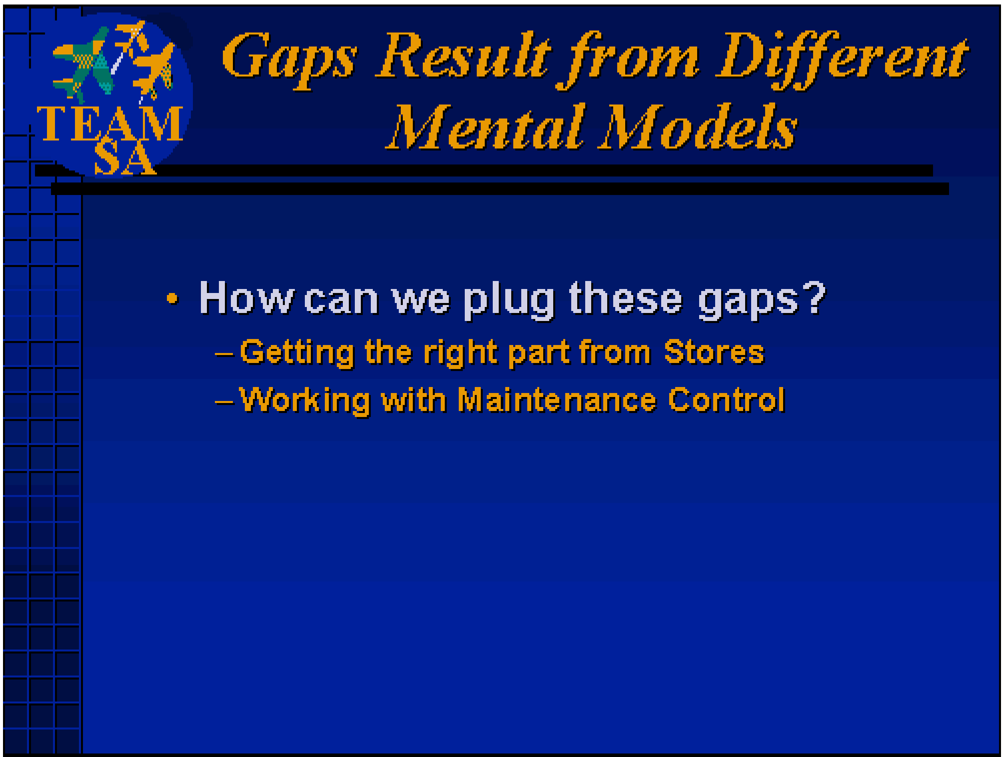

TEAM SA
What is a Mental Model?
• You also have a mental model of how Tech Ops works
– departments
– how they interact with each other
– normal functioning of system
– what can go wrong

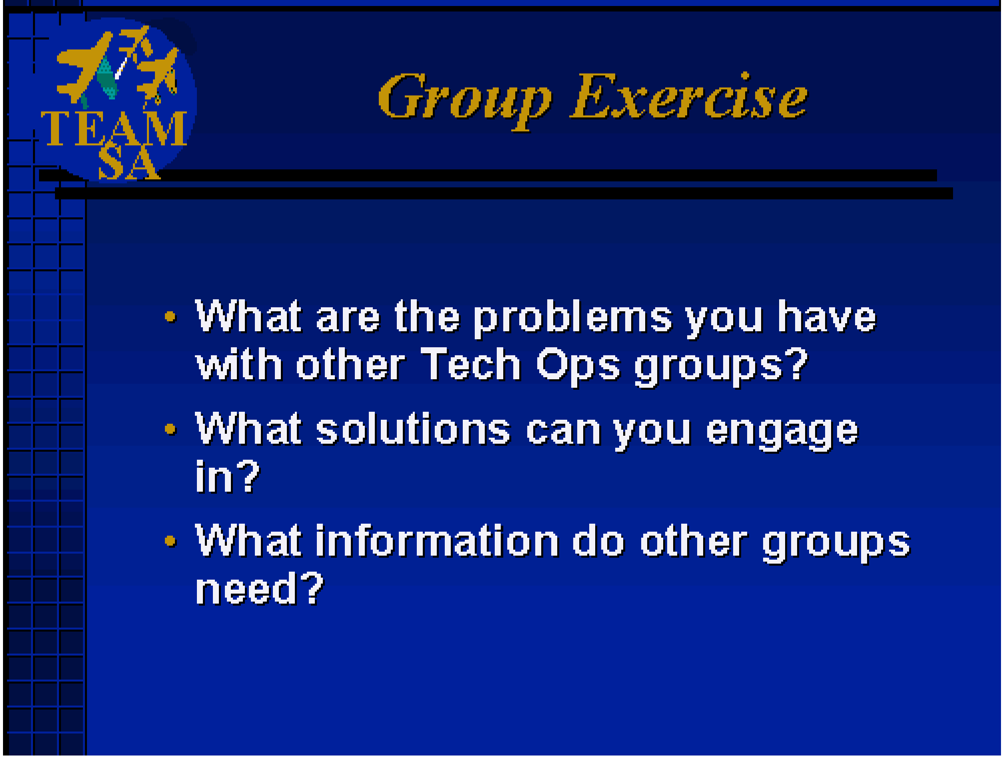

TEAM SA
Everyone's Mental Model Can be Different
Event
Group A
Group B
mental model A
mental model B
Interpretation A
Interpretation B


TEAM SA
Need a Shared Mental Model
Event
Group A
Group B
mental model
mental model
Common Understanding


TEAM SA
Gaps Between Groups
• AMT: "Stores gave me the wrong part"
• Stores: "They didn't give me the right part number again"
– Result
• Extra work for both sides
• More time to do job
• Delays to aircraft
• Potential for loss of airworthiness


TEAM SA
Gaps Between Groups
• AMT: "Those guys in Maintenance Control don't know what its like out here"
• MC: "Those Techs don't tell us everything"
– Result
• lack of trust & communication
• misdiagnosis of problem
• longer time to work through repair

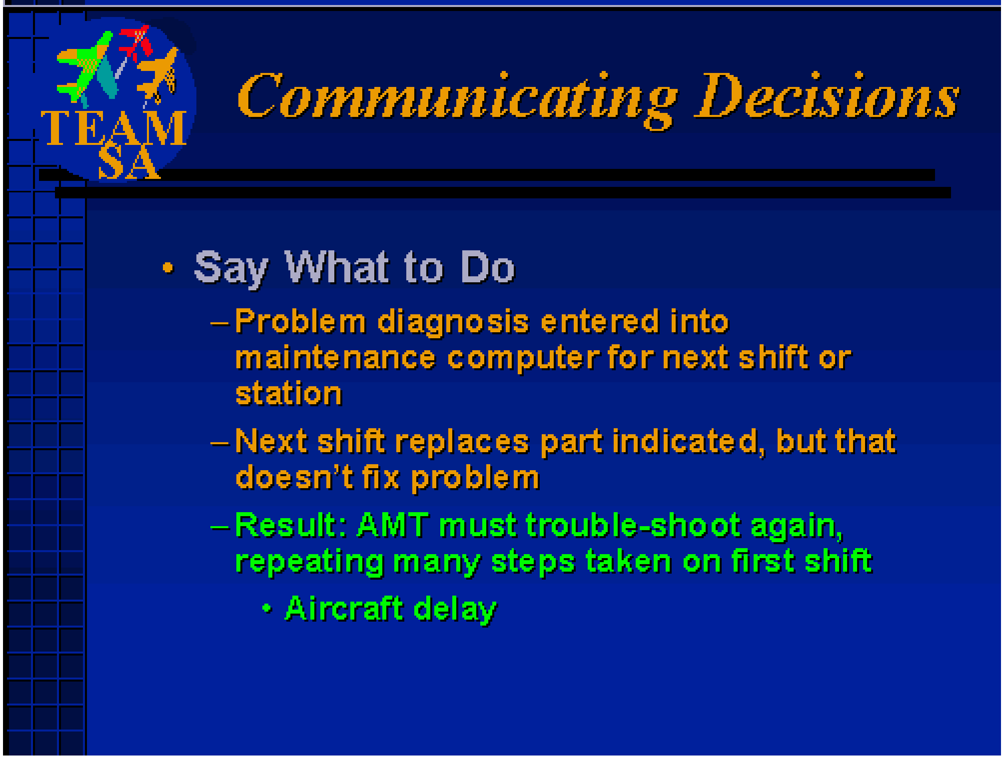

TEAM SA
Gaps Result from Different Mental Models
• How can we plug these gaps?
– Getting the right part from Stores
– Working with Maintenance Control

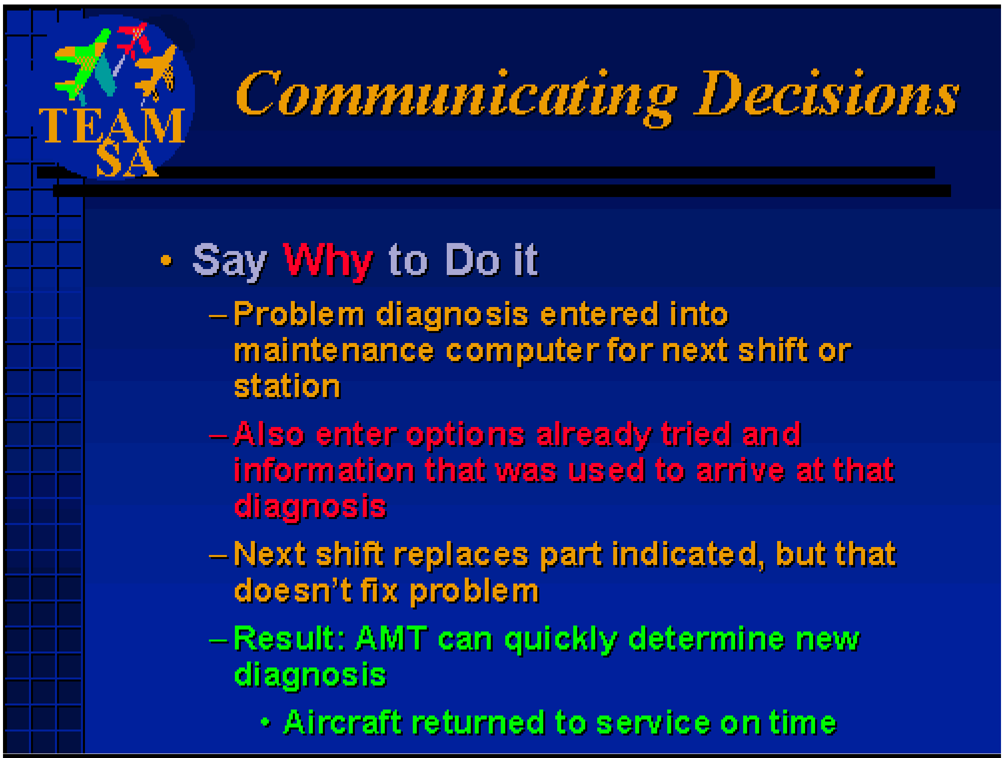

TEAM SA
Group Exercise
• What are the problems you have with other Tech Ops groups?
• What solutions can you engage in?
• What information do other groups need?


TEAM SA
Workshop Agenda
• Introduction: training goals
• Review of MRM concepts
• What is situation awareness?
• Overcoming information gaps between maintenance operations groups
• Communication between teams
• Teamwork and shift meetings
• Use of feedback
• Case study of SA in aviation maintenance


TEAM SA
Communicating Decisions
• Say What to Do
– 3 a.m.: Engine is disassembled and in trouble-shooting. Diagnosis is made.
– Maintenance Control says send plane to CLE for scheduled maintenance
– Result: AMTs can't finish job even though they know the problem and can fix it.
• Issue MEL.
• Lost 3 hours of work.

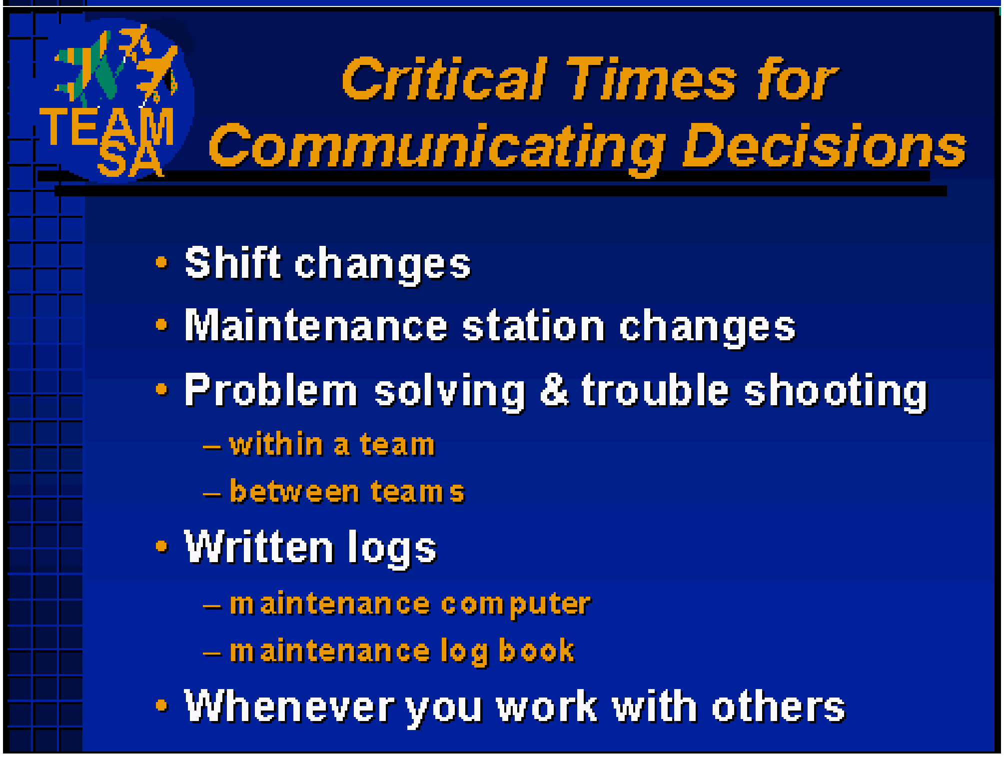

TEAM SA
Communicating Decisions
• Say Why to Do it
– 3 a.m.: Engine is disassembled and in trouble-shooting. Diagnosis is made.
– Maintenance Control says send plane to CLE for scheduled maintenance
• Scheduled maintenance
– Scheduled Maintenance is for carpet change-out
– Result; Why don't we do carpet change-out here so we can finish the job?
• No MEL is needed
• Work is completed without lost time

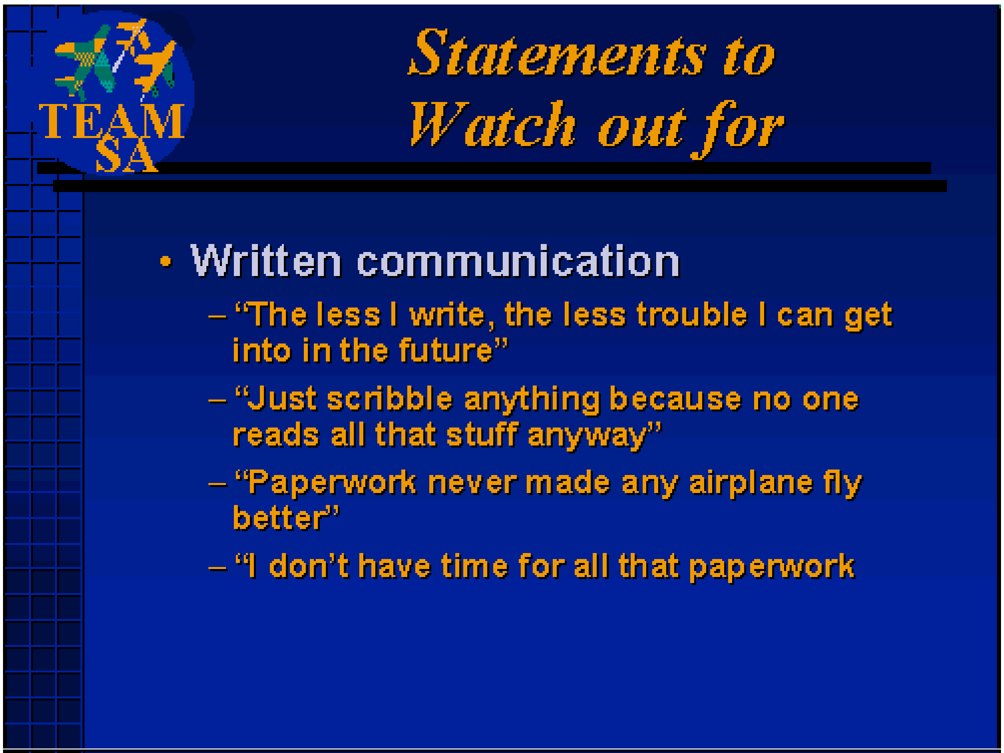

TEAM SA
Communicating Decisions
• Say What to Do
– Problem diagnosis entered into maintenance computer for next shift or station
– Next shift replaces part indicated, but that doesn't fix problem
– Result: AMT must trouble-shoot again, repeating many steps taken on first shift
• Aircraft delay


TEAM SA
Communicating Decisions
• Say Why to Do it
– Problem diagnosis entered into maintenance computer for next shift or station
– Also enter options already tried and information that was used to arrive at that diagnosis
– Next shift replaces part indicated, but that doesn't fix problem
– Result: AMT can quickly determine new diagnosis
• Aircraft returned to service on time


TEAM SA
Importance of Communicating Reasons for Decisions
• Communicate decision
– Do this action
• Communicate Why you made that decision
– Provides better understanding & interpretation of information
– Allows knowledge & ideas of everyone to come into play
– Leads to better solutions than one person acting alone

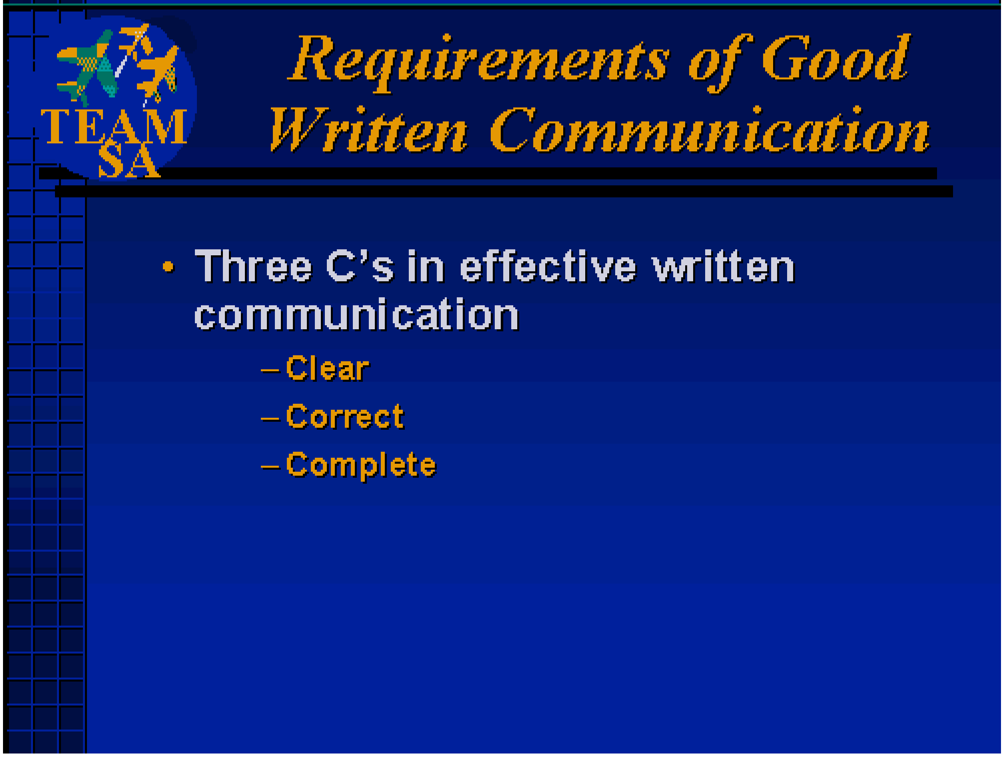

TEAM SA
Who Needs to Communicate Decisions?
• Supervisors
• Leads
• AMT
• All Tech Ops Organizations


TEAM SA
Critical Times for Communicating Decisions
• Shift changes
• Maintenance station changes
• Problem solving & trouble shooting
– within a team
– between teams
• Written logs
– maintenance computer
– maintenance log book
• Whenever you work with others

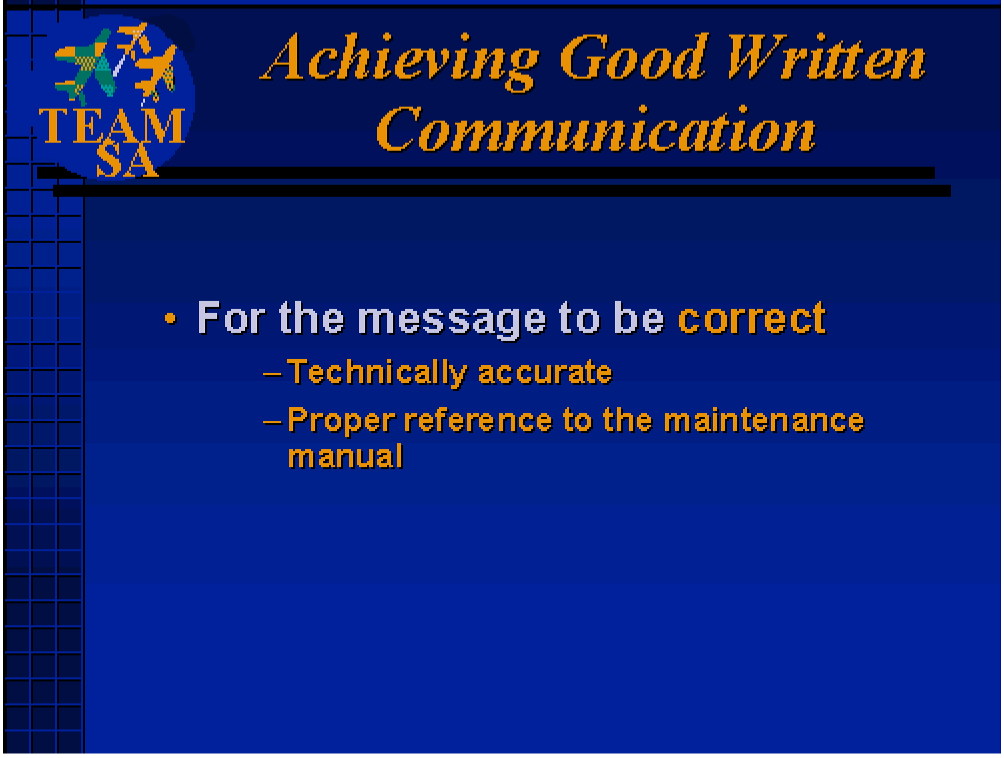

TEAM SA
Statements to Watch out for
• Written communication
– "The less I write, the less trouble I can get into in the future"
– "Just scribble anything because no one reads all that stuff anyway"
– "Paperwork never made any airplane fly better"
– "I don't have time for all that paperwork


TEAM SA
Importance of Written Communication
• Written communication is the most difficult
– limited feedback
– no body language or tonal clues
– The reader cannot ask questions about the meaning or the message

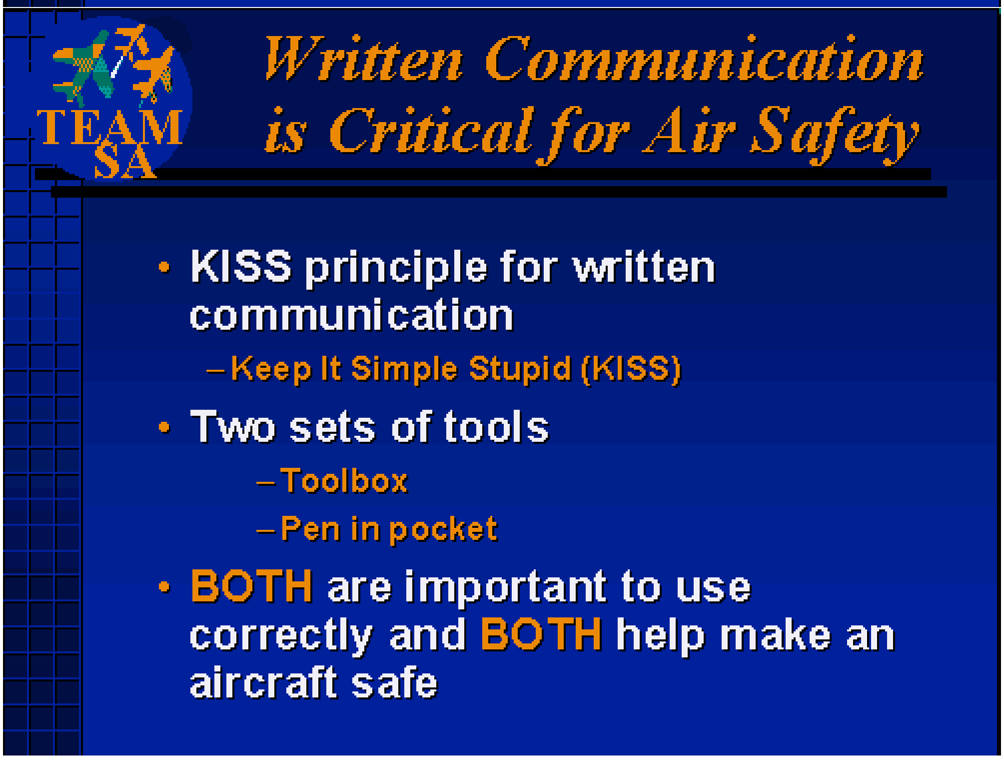

TEAM SA
Requirements of Good Written Communication
Must convey the complete message
Must be easy to understand
Must relate accurately to the problem at hand
Must be readable
Should be free of any emotional or hidden messages


TEAM SA
Requirements of Good Written Communication
Three C's in effective written communication
– Clear
– Correct
– Complete


Achieving Good Written Communication
TEAM SA
• For the message to be clear
– Say what you mean
– State the point
– Use short sentences
– Be careful of acronyms and abbreviations


Achieving Good Written Communication
TEAM SA
• For the message to be correct
– Technically accurate
– Proper reference to the maintenance manual


TEAM SA
Achieving Good Written Communication
• For the message to be complete
– Provide enough information
– One action per step
– Proper sequence
– Be careful of errors of omission


TEAM SA
Written Communication is Critical for Air Safety
• KISS principle for written communication
– Keep It Simple Stupid (KISS)
• Two sets of tools
– Toolbox
– Pen in pocket
• BOTH are important to use correctly and BOTH help make an aircraft safe

Group Exercise

- Watch accident video
  - What was the role of maintenance in this accident?
  - Review maintenance log
  - Rewrite maintenance log

Group Exercise

- Identify
  - Chain of events
  - Communication problems between crews
  - Written communication problems in maintenance log book
- Develop safety nets


TEAM SA
Workshop Agenda
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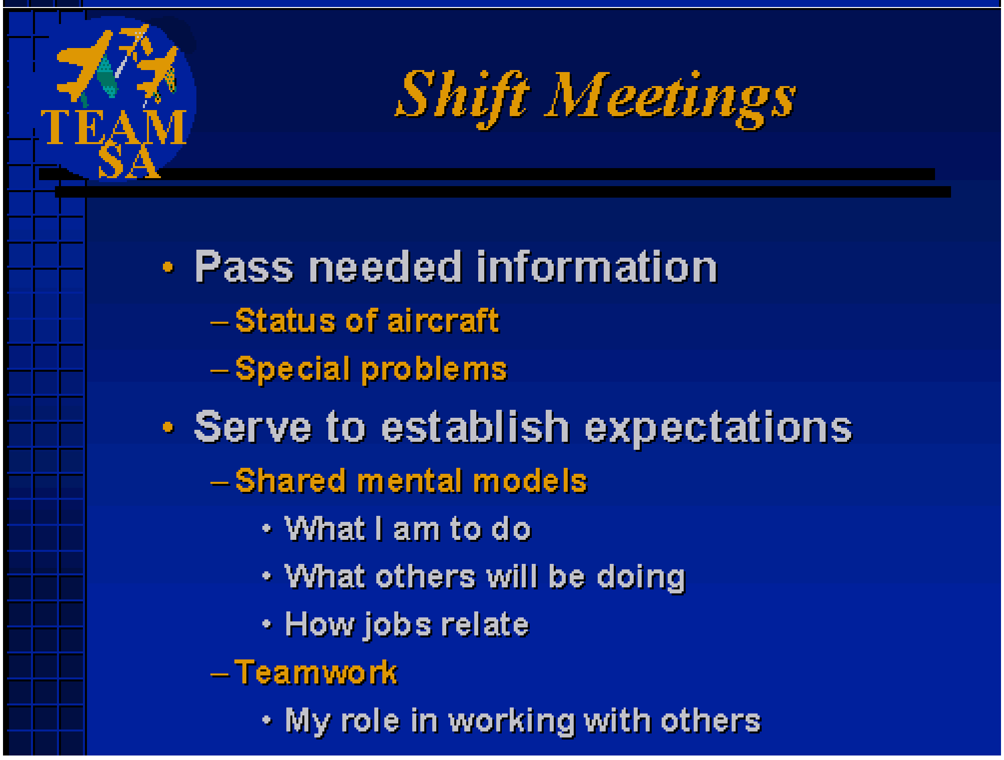
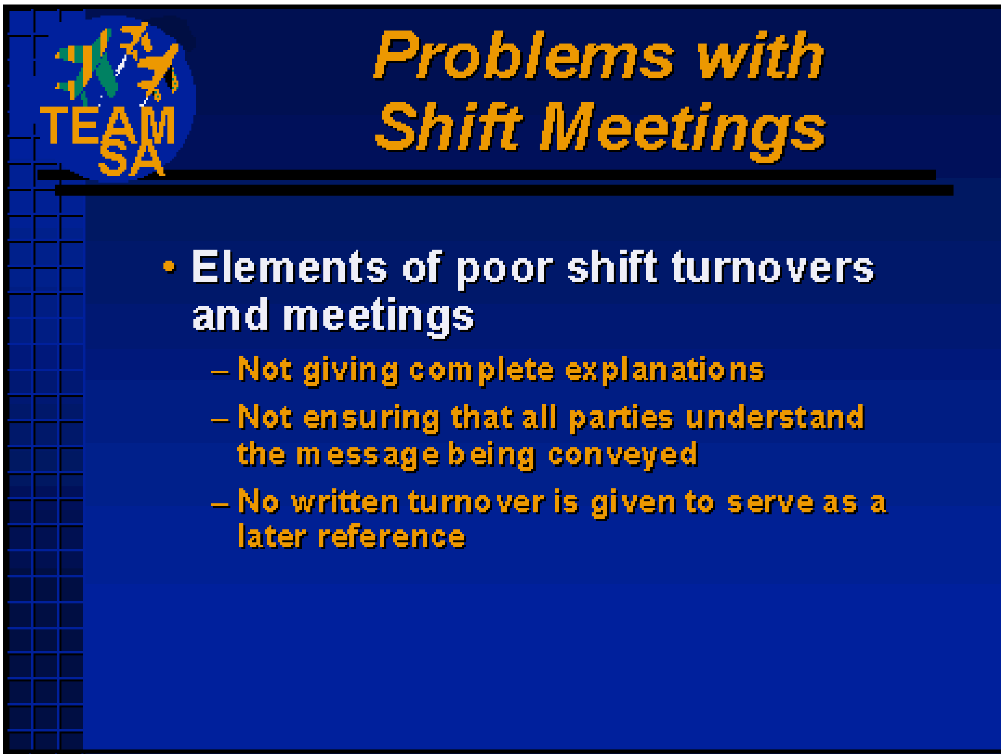
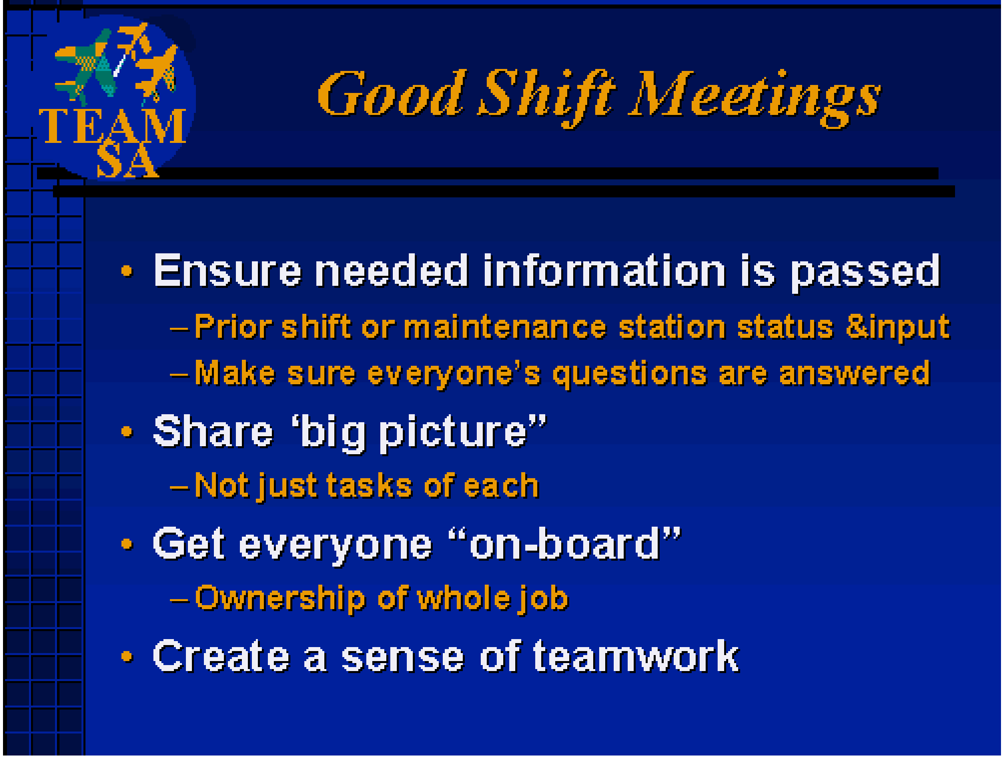

TEAM SA
Shift Meetings
Pass needed information
– Status of aircraft
– Special problems
Serve to establish expectations
– Shared mental models
What I am to do
What others will be doing
How jobs relate
– Teamwork
My role in working with others


TEAM SA
Problems with Shift Meetings
• Elements of poor shift turnovers and meetings
– Not giving complete explanations
– Not ensuring that all parties understand the message being conveyed
– No written turnover is given to serve as a later reference

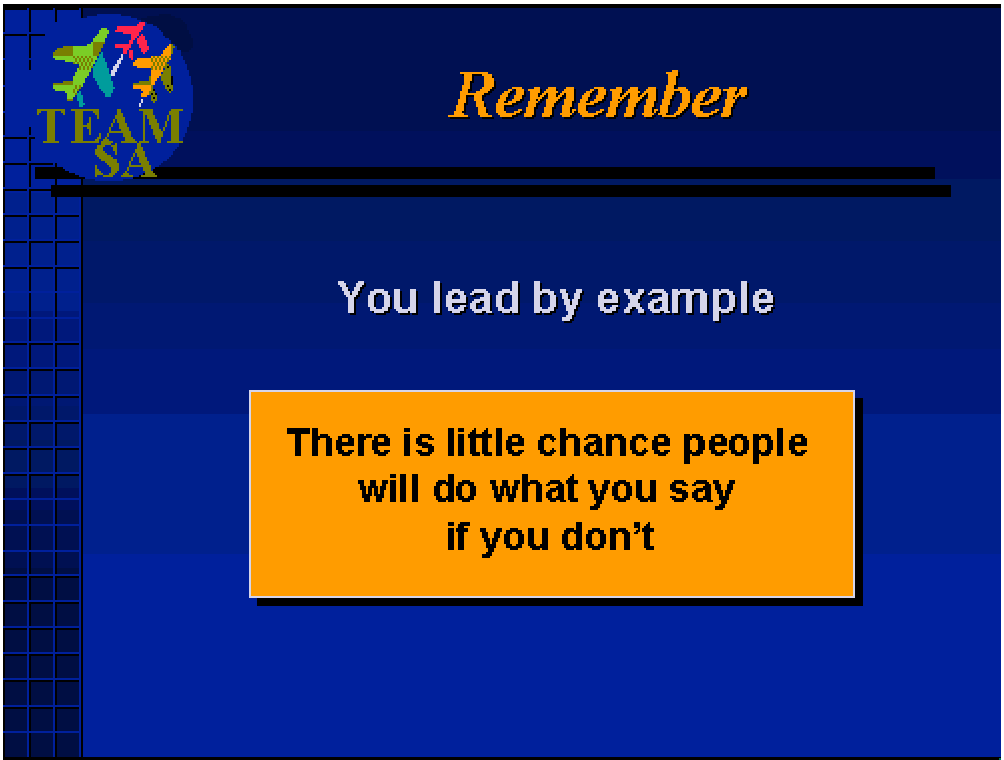

TEAM SA
Good Shift Meetings
• Ensure needed information is passed
– Prior shift or maintenance station status &input
– Make sure everyone's questions are answered
• Share 'big picture"
– Not just tasks of each
• Get everyone "on-board"
– Ownership of whole job
• Create a sense of teamwork

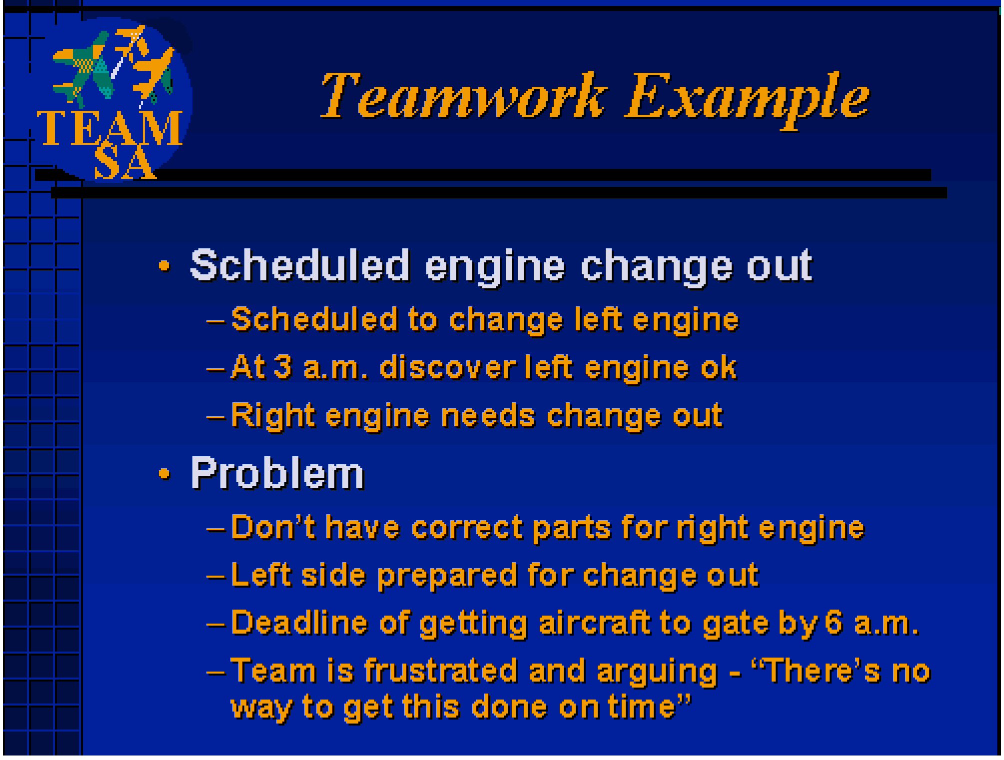
Teamwork Expectations

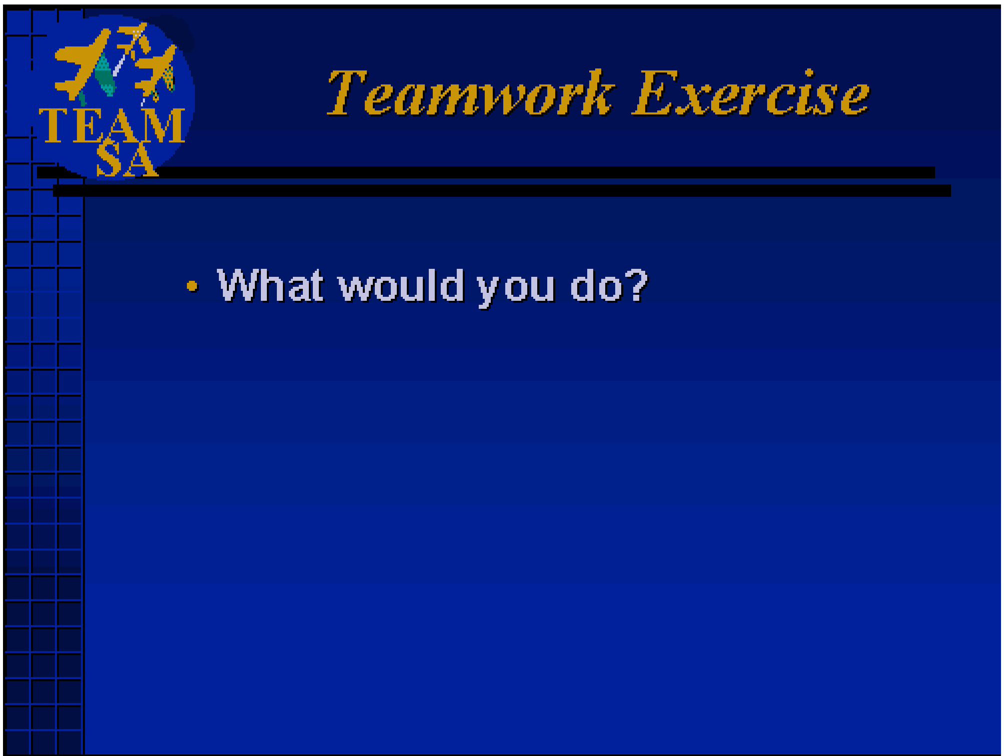
- We're all in this together
  - When you are done with your tasks, work with other team members to help them
  - Team must share an understanding of who's doing what
    - Each team members' job affects the completion of the overall maintenance task
  - Team needs job updates over shift
    - Need updates during shift on status of others tasks
    - How does what I am doing affect others?
    - How are we as a team doing?

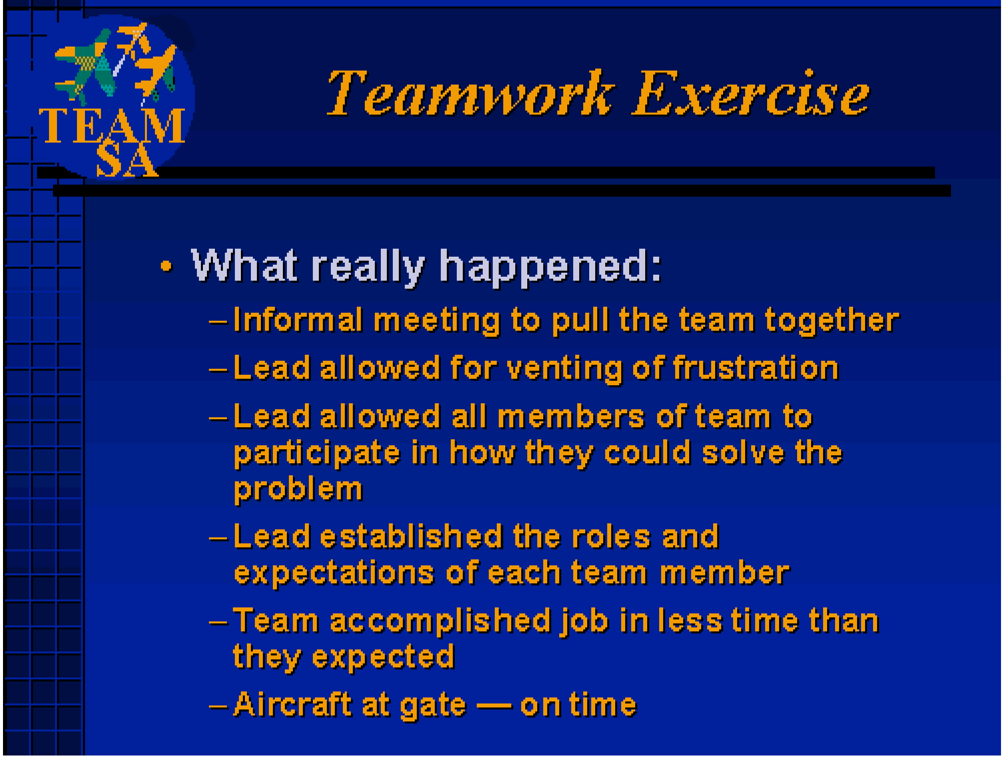
Creating Teamwork

- Allow everyone to participate
  - Creates "ownership"
  - Key to motivation
- Clearly establish ground rules & expectations
  - Teamwork vs. Ownwork
  - Pull together vs. Blame each other
- Clearly establish roles & tasks of each member
  - Provides structure and understanding


TEAM SA
Remember
You lead by example
There is little chance people will do what you say if you don't


TEAM SA
Teamwork Example
• Scheduled engine change out
– Scheduled to change left engine
– At 3 a.m. discover left engine ok
– Right engine needs change out
• Problem
– Don't have correct parts for right engine
– Left side prepared for change out
– Deadline of getting aircraft to gate by 6 a.m.
– Team is frustrated and arguing - "There's no way to get this done on time"


TEAM SA
Teamwork Exercise
• What would you do?


TEAM SA
Teamwork Exercise
• What really happened:
– Informal meeting to pull the team together
– Lead allowed for venting of frustration
– Lead allowed all members of team to participate in how they could solve the problem
– Lead established the roles and expectations of each team member
– Team accomplished job in less time than they expected
– Aircraft at gate — on time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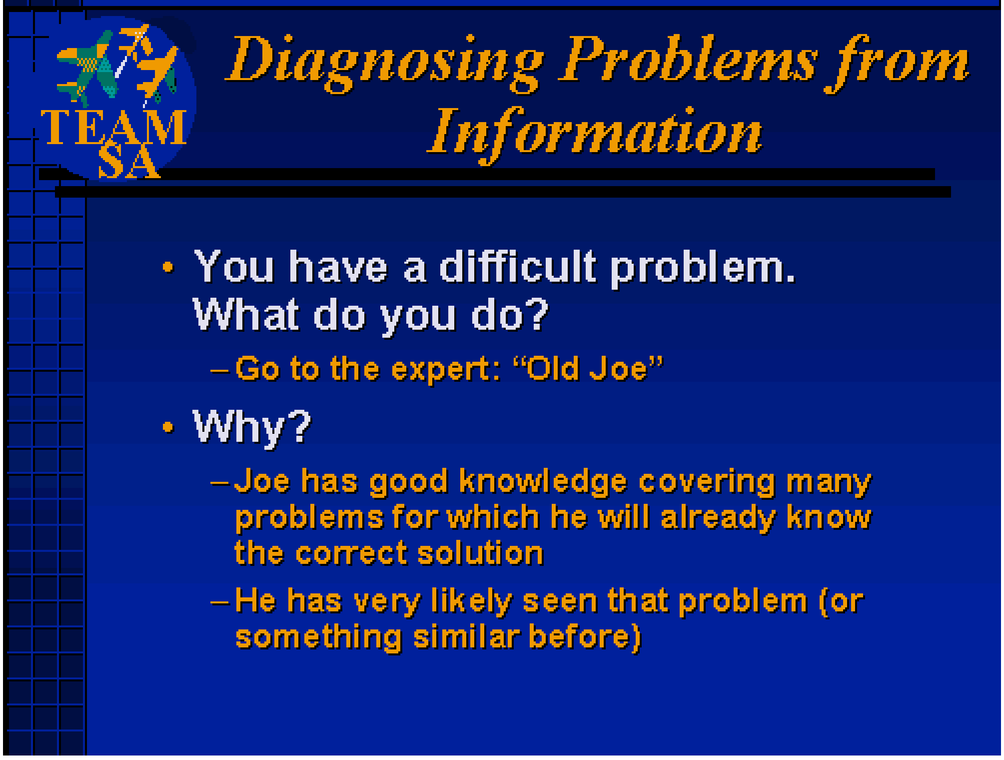
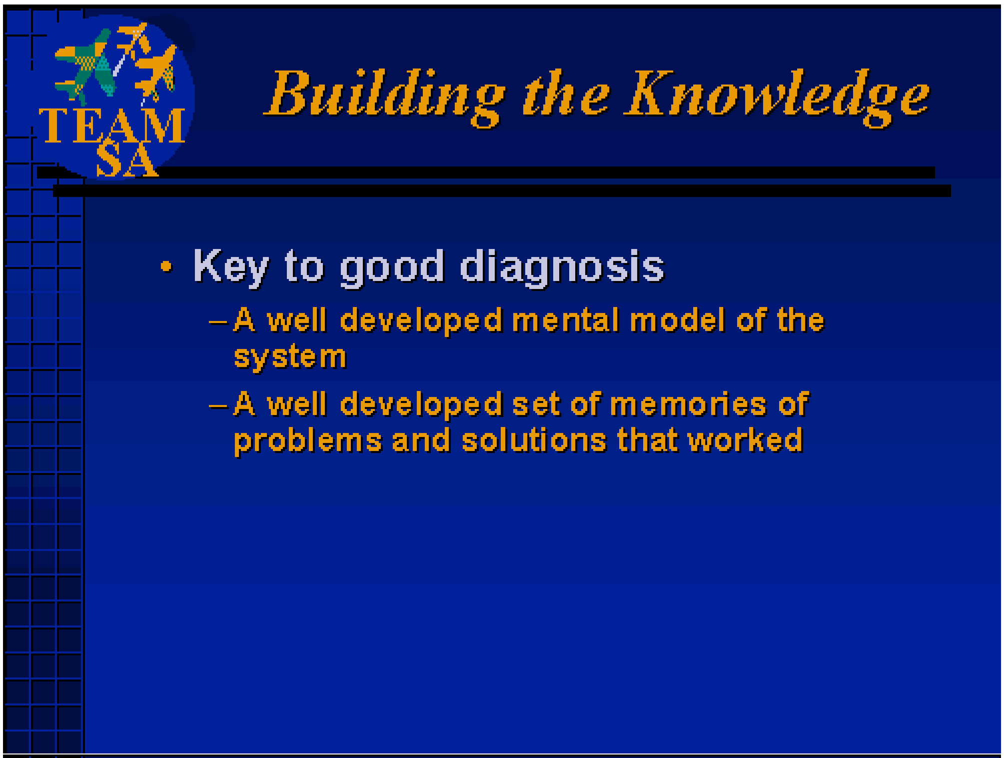
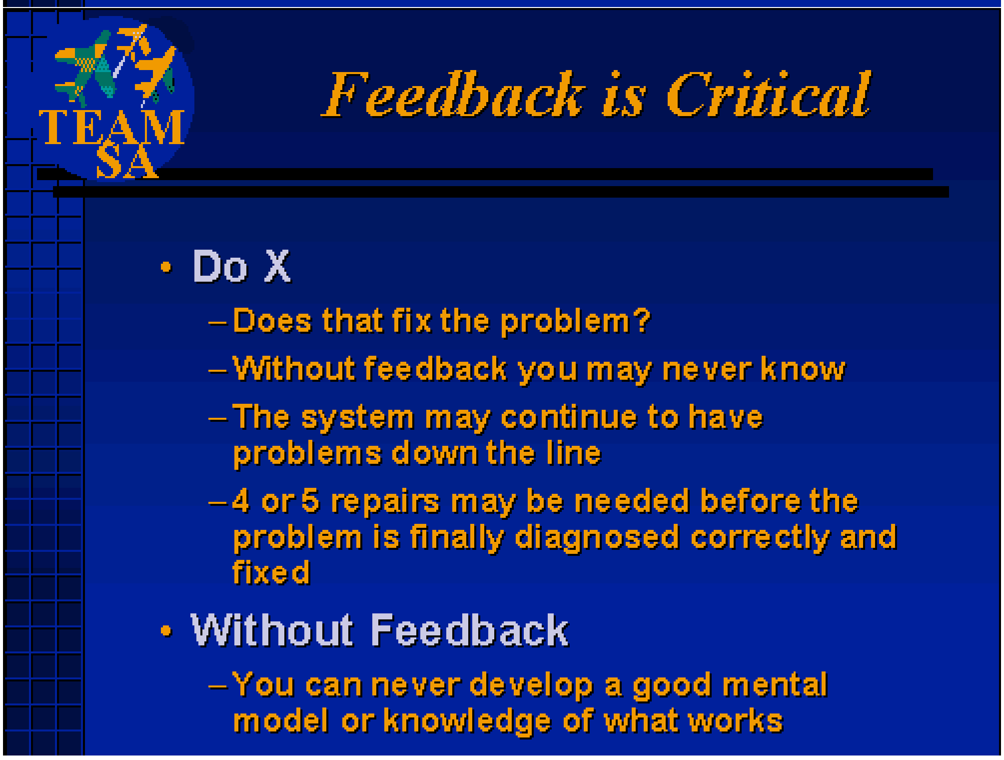
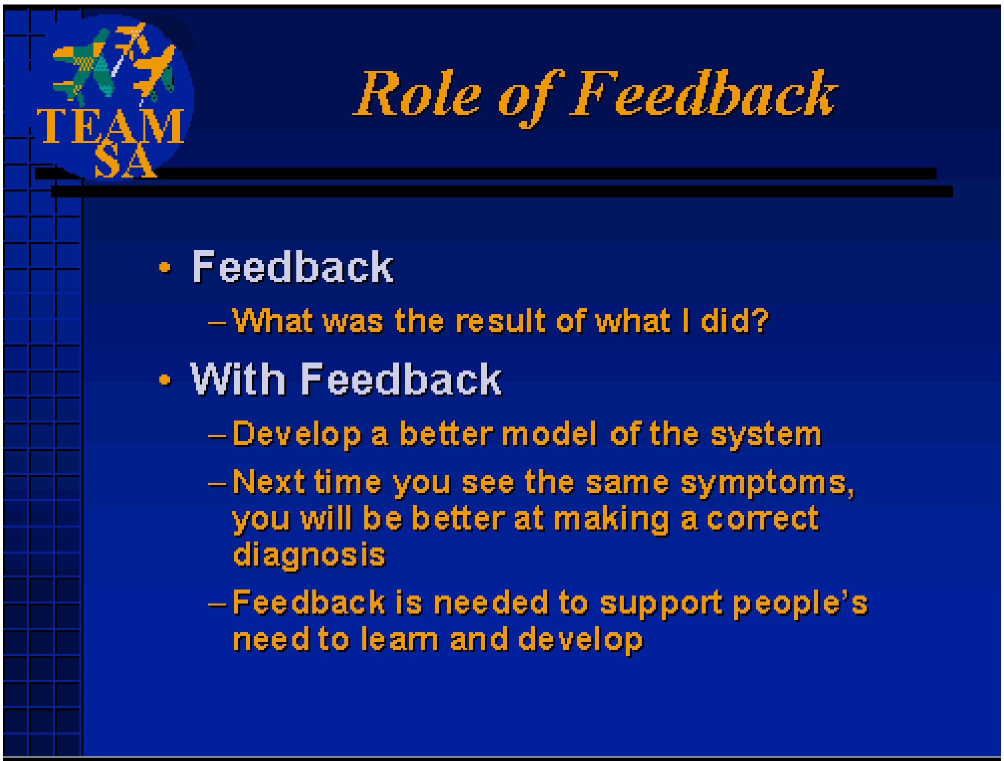
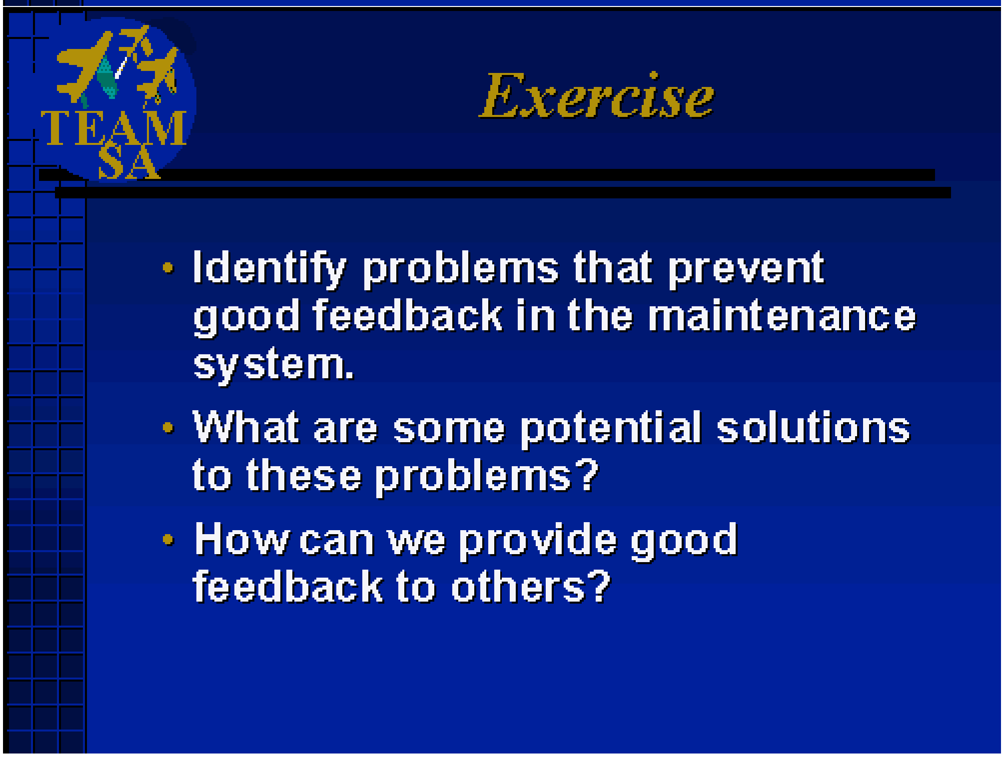
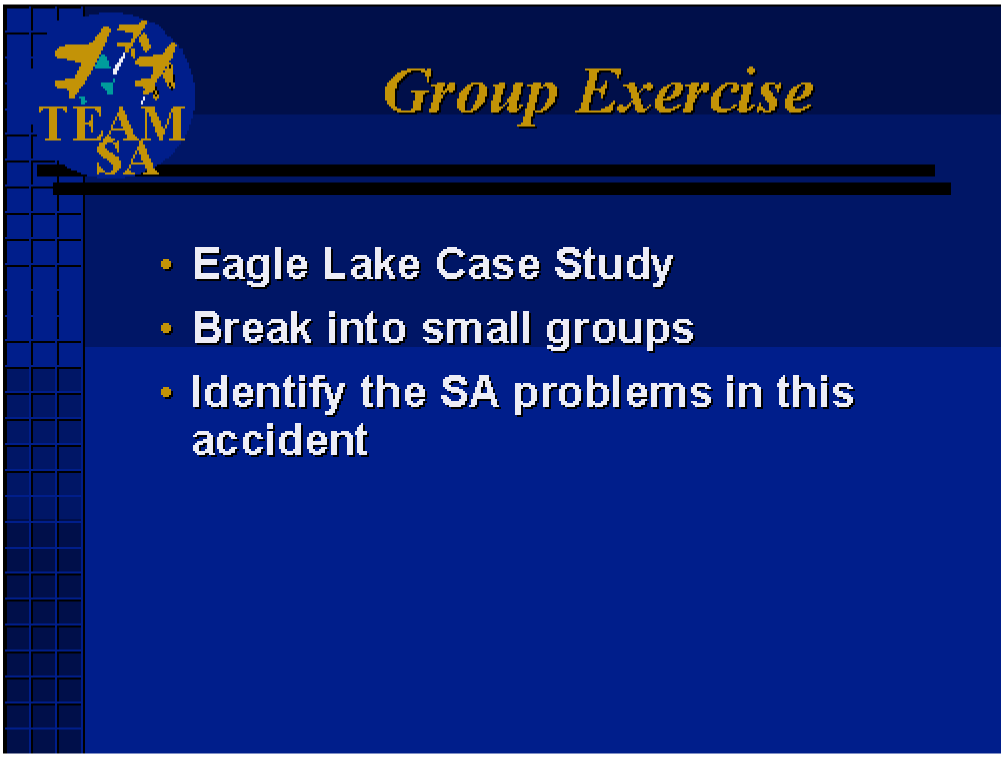

TEAM SA
Diagnosing Problems from Information
You have a difficult problem. What do you do?
– Go to the expert: "Old Joe"
Why?
– Joe has good knowledge covering many problems for which he will already know the correct solution
– He has very likely seen that problem (or something similar before)


TEAM SA
Building the Knowledge
• Key to good diagnosis
– A well developed mental model of the system
– A well developed set of memories of problems and solutions that worked


TEAM SA
Feedback is Critical
• Do X
– Does that fix the problem?
– Without feedback you may never know
– The system may continue to have problems down the line
– 4 or 5 repairs may be needed before the problem is finally diagnosed correctly and fixed
• Without Feedback
– You can never develop a good mental model or knowledge of what works


TEAM SA
Role of Feedback
• Feedback
– What was the result of what I did?
• With Feedback
– Develop a better model of the system
– Next time you see the same symptoms, you will be better at making a correct diagnosis
– Feedback is needed to support people's need to learn and develop


TEAM SA
Exercise
• Identify problems that prevent good feedback in the maintenance system.
• What are some potential solutions to these problems?
• How can we provide good feedback to others?


TEAM SA
Group Exercise
• Eagle Lake Case Study
• Break into small groups
• Identify the SA problems in this accident